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HABIT AND INTELLIGENCE.

HABIT AND INTELLIGENCE:

A SERIES OF ESSAYS

ON THE

LAWS OF LIFE AND MIND.

BY

JOSEPH JOHN MURPHY.

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PREFACE TO THE SECOND EDITION.

This second edition is so nearly re-written as to be practically a new work.

It is now nearly ten years since the first edition was published. Knowledge has been rapidly increasing since then, and, though much occupied with various other matters of deep interest, I have been thinking, reading, and conversing on the subjects of this work, with the result, that while I have seen reason to change my opinions on many subordinate questions, I am as deeply convinced as ever of the necessity for recognising the action in all life, both organic and mental, of an intelligent agency which cannot be explained as a resultant from unintelligent forces.

The Introduction to the first edition, which consisted of an essay on historical methods in science, is not republished; and the Preface to the first edition is printed, with no important change, as the Introduction to this.

I have omitted all the chapters of the first edition which treated of merely physical science, as distinguished from the science of Life and Mind, as well as those which consist of mere *résumés* of generally known facts and laws bearing

on the doctrine of Evolution. I have also omitted the chapter on the Senses, and the three chapters on the Classification, the History, and the Logic of the Sciences. With the exception of that on the Senses, which does not seem worth republication, the purpose of these omissions has been merely to avoid making the work too bulky with material which is not directly relevant to its main subject.

On the other hand, chapters have been inserted on the Facts of Variation, on the Effect of Change of Conditions, and on Mimicry, Colour, and Sexual Selection. These are mostly abstracted from the enormous mass of detail noted in Darwin's works; and I hope that they may be not only serviceable in illustrating the reasonings of this work, but useful in themselves as constituting an accurate and readable summary of interesting and important facts. The following chapters are also altogether new, and are the most original in the work:—

Classification and Parallel Variation. (Chapter XIII.)

Classification and the Fixation of Characters. (Chapter XIV.)

Structure in Anticipation of Function. (Chapter XVIII.)

The Origin of Man. (Chapter XIX.)

Automatism. (Chapter XXXII.)

The chapter on Metamorphosis and Metagenesis is mostly new. The psychological chapters are re-written and much improved; and there are few chapters which are not in a considerable degree re-written.

I have to express my obligation to my friend Dr. Cunningham, Professor of Natural History at Queen's College, Belfast, for much valuable information, and for his kindness in revising the proofs of the zoological chapters; and to my friend Frederic Purser for his kindness in doing the same for the psychological chapters. This does not however make either of those gentlemen in any way responsible for the opinions I have expressed.

JOSEPH JOHN MURPHY.

OLD FORGE, DUNMURRY, CO. ANTRIM,
29th October, 1878.

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CORRIGENDA.

The statement on page 81, that "the Hydrozoa have no vestige of a nervous system," was in print before Mr. Romanes published his researches on Medusæ (or jelly-fish). He appears to have proved that although no nerve-fibres can be seen in their substance, yet experiment shows the existence of tolerably definite tracks for the conduction of stimuli, which must be regarded as incipient nerves.

Page 234, title of diagram, for *Spidosteus*, read *Lepidosteus*.

Page 336, title of diagram, for *Tabularia*, read *Tubularia*.

Page 350, fourth line from bottom, for *Darwinism*, read *Darwinian*.

Page 390, beginning of third line from commencement of third paragraph, for *possible*, read *probable*.

Page 405, heading of second paragraph, for *instructive*, read *instinctive*.

HABIT AND INTELLIGENCE.

INTRODUCTION.

Many of the speculations propounded in this work, as well as its entire plan, are original. It may consequently be of service to the reader to have it introduced by a brief account of its purpose and of its leading ideas, written from the author's point of view.

Subject of this Work.—Its chief purpose is to investigate the special and characteristic principles of both unconscious and conscious life—in commoner language, of life and mind. It commences by treating of the relation of life to ordinary matter and force; but its most important part is that which treats of those vital principles which belong to the inner domain of life itself, as distinguished from the principles which belong to the border-land where life comes into contact with inorganic matter and force. To that border-land belong such laws as those of nutrition and respiration; while to the inner domain of life belong the laws of organization and of mind.

In this inner domain of life, on which dynamics and chemistry have scarcely any light to throw, we find two principles which are, as I believe, co-extensive with life and peculiar to it: these are Habit and Intelligence.

Habit.—I am compelled to use the word Habit in an unusually wide sense. I mean by habit, that law in virtue of which all the actions and the characters of living beings tend to repeat and to perpetuate themselves, not only in the individual but in its offspring. This law is fundamental in both the unconscious and in the conscious life; or, to use commoner language, it is a fundamental law of life and mind. The law of the association of ideas, which is justly regarded as a fundamental law of mind, is only a case of the law of habit. I make as full a statement as I am able to do of the laws under which habits form, disappear, change under altered circumstances, and vary spontaneously.

Intelligence.—The word Intelligence scarcely needs definition, as it is used in its familiar sense. It will not be questioned by anyone that intelligence is found in none but living beings; but it is not so obvious that intelligence is an attribute of all living beings, and co-extensive with life. When I speak of intelligence, however, I mean not only the conscious intelligence of the mind, but also the organizing intelligence which adapts the eye for seeing, the ear for hearing, and every other part of an organism for its work. The usual belief is, that the organizing intelligence and the mental intelligence are two distinct intelligences. I maintain, on the contrary, that they are not distinct, but are two separate manifestations of the same intelligence, which is co-extensive with life, though it is for the most part unconscious, and only becomes fully conscious of itself in the brain of man.

Habit is in itself obviously an unintelligent principle. No intelligence is involved in the mere tendency to repeat an action or to perpetuate a character. But when the laws of Habit and of Intelligence have been stated, the question arises whether intelligence is an ultimate fact, incapable of being resolved into any other, or only a resultant from the laws of

habit. This is by far the most important of all questions now under scientific discussion, and perhaps the most important that science can ever have to consider.

From the point of view adopted in this work, this question divides itself into two: the one, concerning the unconscious intelligence that organizes the body; the other, concerning the conscious intelligence of mind.

Origin of Species.—The inquiry concerning the nature of the organizing intelligence involves an examination of that question of the origin of species which, since the publication of Darwin's great work on the subject, has probably attracted more interest than any other scientific question. I agree with Darwin in the belief that all species have been derived by descent with modification, probably from one, certainly from a few, original germs; and I further agree with him in attaching great importance to "natural selection among spontaneous variations" as part of the agency by which the modifications have been effected. But I altogether differ from him, in that I believe the wondrous facts of organic adaptation cannot have been produced by natural selection, or by any unintelligent agency whatever.

Mental Intelligence.—As on the subject of organizing intelligence I have come to a conclusion which is fundamentally opposed to that of Darwin, so on that of mental or conscious intelligence I have come to a conclusion which is fundamentally opposed to that of the dominant psychological school in this country:—the school which was founded by Hartley, and to which Mill, Bain, and Herbert Spencer belong. The characteristic point of their theory is, that they endeavour to account for the whole mental nature by the single principle of the association of ideas, or, as I call it, of mental habit. I

maintain, on the contrary, that in all mental intelligence, as in organizing intelligence, there is an element not derived from habit, and not resolvable into any unintelligent agency whatever.

In the concluding chapters I endeavour to show how the science of history is capable of being elucidated by the same principles which have thrown so much light on the development of individual organisms and of organic species.

I abstain as much as possible from technical language and technical modes of statement. It is my aim to make the subjects treated of intelligible to any intelligent person who is willing to give the necessary attention, and to remove all difficulties except such as are inseparable from subjects which have not yet become familiar. I endeavour to give my authority for all important statements as to facts which are not matters of general notoriety; and when I advance any opinion of my own, I advance it as such.

Further Questions.—In several places throughout this work, we are brought to the borders of a region external to that which is usually regarded as the domain of science. Such subjects as the origin of the universe, the origin of life, the nature of intelligence, and the nature and ground of the moral sense, suggest questions which, if they are to be answered at all, must be answered from data which are not to be found in the visible world. It is not from indifference to that class of questions, but rather from a conviction of their transcendent importance, that I do not enter on them in this work. I have treated of them in a distinct work entitled *The Scientific Bases of Faith.*[1]

[1] Macmillan, 1873.

CHAPTER I.

THE CHEMISTRY OF LIFE.

SUCH a work as this ought to be commenced by an attempt to define "life," or, in other words, to state what is the differentia of life.

Life defined as a Process of Assimilation and Waste.—Modern investigation among the lowest organisms has made the line that separates life from dead matter appear narrower than it formerly seemed; nevertheless it remains perfectly definite. Organization no longer appears necessary to the existence of a living being; there are minute beings which have scarcely a trace of organization, and yet are shown by their actions to be alive. Organization is now seen not to be the cause nor even the differentia of life, but only one of its most general results. The differentia of life is to be sought in the nutritive process. De Blainville has defined life as "a double internal motion, general and continuous, of composition and decomposition," meaning, in more familiar language, that life is a process of assimilation and waste. This, however, must be stated more fully.

A living organism is constantly receiving new substance from without by accretion, and losing substance by excretion or waste. Growth is due to the excess of accretion over waste. But the constant parting with old material and acquiring new material do not of themselves constitute life. If they did, a glacier would come under the definition; for it is constantly losing material

by melting away below, and gaining material in the snow that descends from above. The word accretion sufficiently describes the deposit of new material to which is due the increase of a glacier, or a crystal, or any other inorganic growth. But there is this remarkable difference between organic and inorganic growth, that the accretion by which an inorganic mass grows is superficial: in the case of an organism, on the contrary, it is interstitial. And this is connected with a still profounder difference; namely, that new substance, in the act of becoming part of the substance of an organism, has a change wrought upon it by the agency of the organism itself, which makes it similar to the rest of the substance of the organism in chemical and molecular constitution. This process is what is called assimilation. The power of growth by assimilation appears essential to life: and the parallel process of waste is general, if not absolutely universal, among living beings.[1] Everyone knows that waste is constantly going on from animals, and it has been ascertained that vegetables, as well as animals, are constantly giving off carbonic acid, which can only come from the waste of their substance. We thus conclude that a living organism is constantly losing substance by waste; and if, among the lowest organisms, there are any exceptions to this law, there are certainly no exceptions whatever to the law that a living organism acquires new substance which it transforms into its own substance by assimilation.

This relation between life and matter has been usually regarded as the most important if not the only essential character of

[1] If there are any exceptions to the universality of the process of waste, they can be only among the lowest organisms. "In the process of putrefaction, the researches of Pasteur have shown that so far from oxygen being necessary to the life of the simple living beings concerned, there are certain forms of infusoria which not only pass their lives without oxygen, but are killed by its presence."—(Beale's edition of Todd and Bowman's *Physiology*, p. 19.) What Pasteur here regards as infusoria must, I think, be rather vegetable than animal. But whether this is so or not, it is not easy to see how waste can go on in organisms that never come in contact with oxygen, and where, consequently, oxidation is impossible.

living beings; but in the next chapter we shall see reasons for believing that there is an equally general and important relation between life and energy.

Absolute Distinction of Organic Chemistry from Inorganic.—The substance of living beings consists of chemical compounds of high complexity, which appear incapable of being formed by any inorganic chemistry. This last statement may be questioned; perhaps many readers will think it is contradicted by those wonderful discoveries of late years in organic chemistry, which have made it possible to form many of the so-called organic compounds from their elements by the inorganic processes of the laboratory. The opinion appears to have gained ground, that there is no absolute distinction between organic and inorganic products, and that with increasing chemical knowledge we may hope to form in the laboratory every substance which we know as a product of vital action. I cannot however think so. The most characteristically organic, or vital, products are those of the albuminoid class; and I cannot think it possible that they can ever be formed by any chemistry except that of the organism of living vegetables. Animals cannot form them. All animals feed either on vegetables, or on other animals which have fed on vegetables; they receive the albuminoid compounds in their food; these undergo a process of assimilation in the animal's system which makes them fit to be incorporated with its tissues. If the albuminoid and other characteristically organic compounds could be formed by any inorganic chemistry, it would be possible for man and his domestic animals to obtain their food from chemical manufactories, and to be independent of the vegetable world; and this appears altogether beyond possibility.

The truth on this subject appears to be, that the albuminoid class of substances, which are those which appear most essential to the vital processes of both animals and vegetables, can only be formed in, and by, an organism; and that those so-called organic products which have been made in the laboratory are not capable of forming part of any living tissue, but are only

products of the decomposition of living tissue.[1] I do not say that they are all waste products. Urea, which was the first organic compound that was made in the laboratory, is no doubt a mere waste product. But this is not true of butyric ether, the flavouring matter of the pine-apple; amylic ether, the flavouring matter of the pear; and formic acid, which is produced by ants.[2] These have all been made in the laboratory, and yet they are not waste products; on the contrary, they are stored in the organism for purposes connected with its economy. But they are not capable of forming part of any living tissue. The truly organic compounds—those, I mean, which constitute the substances in which the vital processes go on—are colloidal, or gelatinous. Formic acid and the ethers, on the contrary, belong to the crystalloidal[3] class of substances, which may be solid and may be liquid, but cannot assume the intermediate gelatinous form; and though many of these, as for instance water, are necessary to life, they cannot become part of any living tissue—in a word, they cannot be vitalised—unless they enter into combination, and in so doing change their character.

Life works through the Physical and Chemical Forces.—The most characteristically vital products appear to be formed by the action of the ordinary chemical forces, modified and guided by that

[1] "The substances already formed in the laboratory by synthesis correspond with those which are produced by the chemical action of oxygen upon products resulting from the disintegration of more complex chemical substances. . . . . . They are the results of a long series of chemical changes occurring in the organism, and are so far removed from the actual constituents of the tissues, and from the substances which immediately result from the death of living matter, that their artificial production affords no safe grounds for supposing that the former complex substances will ever be manufactured in the laboratory."—Beale's edition of Todd and Bowman's *Physiology*, pp. 9, 10.

[2] See *Quarterly Journal of Science*, Jan. 1866, p. 36.

[3] I do not mean that they have been crystallized. But this is not the only test of crystalloidal nature. Only crystalloids have a strong flavour of any kind; and strong flavour is a characteristic of the substances mentioned in the text. This property is no doubt a result of their diffusibility in water, by reason of which they are able, when in solution, to come into contact with the extremities of the nerves of taste.

of the vital principle. Life works not by opposing the physical and chemical forces, nor by suspending their action; on the contrary, it works through them. The relation of life to the lower forces may be compared with the relation of the mechanical engineer to the steam-driven machinery which he constructs and works; he does not set aside the properties of iron and the force of steam; he avails himself of them, and works through them to the production of effects which the iron and the steam could not have produced of themselves.

Selective Assimilation.—The most elementary instance of the way in which the chemical forces are controlled by the vital, is to be found in the facts of selective assimilation. If two different species of plants are grown in the same soil side by side, the chemical constitution of their ashes when burned, that is to say of the solid ingredients derived from the soil, will be different. Thus, the silica assimilated by corn plants amounts to about 2·5 per cent., and by leguminous plants to only 0·3 per cent. of the weight of the plant when dry.[1] This is a chemical result, for which no merely chemical forces will account.

Secretion.—The facts of secretion afford an equally good instance of the same principle. One gland separates bile from the blood, another milk, a third urine, &c., substances of very different chemical constitution; yet all these glands are of almost exactly similar material, and there is no difference between them which can in the slightest degree explain the difference of their actions.

In a future chapter I shall endeavour to justify the way in which I have here assumed the existence of a distinct vital principle.

[1] Alfred Bennett, in the *Popular Science Review*, 1872, p. 372.

CHAPTER II.

THE DYNAMICS OF LIFE.

In order to understand the subject of the present chapter, it is necessary to have a clear idea of what is meant by energy and its transformations: and these are still so unfamiliar to many readers, that it is worth while to begin with a somewhat elaborate explanation.

Energy defined as that which does work.—Energy may be defined as that which does work. Equal quantities of energy are those which are capable of doing equal quantities of work: or, to speak more definitely, those which are capable of overcoming equal resistances (*e.g.* raising equal weights) through equal spaces.

Difference between Force and Energy.—Energy is not synonymous with force. All energy has its origin in force, but force cannot pass into energy unless it is at liberty to act. Thus the ocean presses on its bed with a pressure proportionate to the depth, but no energy is due to this pressure, because there is no space through which the water can fall. But to the position of the water in a mill-pond, or of any other raised weight, a quantity of energy is due, which is measured by the weight multiplied into the height through which it is capable of falling.

Potential and Actual Energy.—Such energy as this is potential energy. When energy ceases to be potential it becomes

actual.[1] The actual energy of a moving body is proportionate to its mass multiplied into the height through which it must have fallen in order to acquire its velocity.

Potential and actual energy are in constant process of transformation, the one into the other. The simplest case of this is the oscillation of a pendulum. During the descent of the pendulum-bob, a quantity of energy proportionate to the vertical height through which it descends is transformed into the actual energy, or energy of motion, due to its velocity at the lowest point of its stroke; and when the pendulum-bob rises to its former height on the opposite side, this actual energy is transformed back again into the potential energy due to the raising of its weight. The transformation of energy thus effected is a simple type on a small scale of what is constantly going on in endless complexity and on the vastest scale throughout the universe.

Energy may be stored.—The Hydraulic Accumulator.—Energy, like matter, is measurable by quantity; and, like matter, energy is capable of being stored. A mill-pond is a means of storing energy; and a still better instance, though exactly the same in principle, is Sir William Armstrong's hydraulic accumulator. This is a contrivance for enabling a small steam-engine, or other source of motive power, to do very heavy work for a short period of time. It consists of a forcing-pump, through the action of which, by hydraulic pressure, the motive power of the steam-engine raises a very heavy weight. A quantity of potential energy, proportionate to the weight multiplied into the height through which it is raised, is thus accumulated; and when it is desired to give out energy and do work, this is done by letting the weight descend, and using its

[1] I should prefer the words *static* and *dynamic* to *potential* and *actual*, because of the distinction of static and dynamic electricity, which is a particular case of the distinction between potential and actual energy; and also because energy never, in any ordinary sense of the word, ceases to be actual. But it is not worth while to quarrel with the established use of these terms.

pressure as motive power. The steam-engine, being small, raises the weight slowly; but the weight is able to descend rapidly, so that the potential energy which is stored up through a comparatively long time may be given out in a short time, and employed in work that requires a great expenditure of energy in a short time, as, for instance, in lifting great weights.[1]

The Conservation of Energy and its Transformations.—Energy, like matter, can be neither produced nor destroyed by any process whatever. Whatever quantity of energy has been expended in doing work reappears as energy.

The indestructibility of energy, like the indestructibility of matter, is contrary to appearance. But energy, like matter, when it appears to be destroyed is really transformed. For instance, when a railway train is stopped by the action of the break, or when a cannon-ball sticks fast in a bank of earth, the energy of motion which has disappeared is transformed into heat. The heat produced by mechanical action, such as friction or collision, is not a mere concomitant of the mechanical action: it is energy of motion which has been transferred from the mass to the molecules.

This truth of the indestructibility—or, technically, the conservation—of energy, is probably the most important discovery that has been made in physical science since Newton proved the universality of gravitation. The laws of energy and its transformations constitute as important a part of science as the laws of matter and its transformations; and this makes probable what I shall endeavour in the present chapter to demonstrate, namely, that the relation of life to energy will be found to be as peculiar and as important as its relation to matter.

[1] It may appear from the text that energy is synonymous with motive power. This, however, is not the case: all motive power is energy, but all energy is not motive power. Heat is a form of energy, and heat becomes motive power in the steam-engine; but heat can become motive power only in the act of attaining equilibrium; it cannot do so after equilibrium is attained. A steam-engine could do no work if the condenser were as hot as the boiler.

The transformations of energy already mentioned are by no means its only transformations. Heat is capable of assuming the radiant form, which is really a perfectly distinct form of energy; and the energy of motion which in friction is usually transformed into heat, may by suitable arrangements be transformed into electricity, either static, as in the charge of a Leyden jar, or dynamic, as in the current along a conducting wire. In the act of straining a spring, again, a charge of energy is taken up, which re-appears and does work when the spring returns to its unstrained state; and it appears highly probable, if not quite certain, that the electrified and magnetized states of bodies consist in the straining of certain molecular elasticities.

Chemical Energies transformed into Heat during Combination.— Energy is given out in most cases of chemical combination. It generally appears as heat, but when the combination occurs under the peculiar arrangements of the voltaic battery, it appears as electricity. The energy which thus becomes actual, was of course potential in the elements before their combination. Energy is thus given out in most if not in all cases where the combination is due to the spontaneous affinities of the elements; and when the disengagement of heat is great and rapid, the act of combination is called combustion.[1] And when

[1] It is most important to understand, that in all cases of spontaneous combination the energy *is parted with.* In ordinary dynamics every one understands this: every one is perfectly well aware that when the water of a mill-stream has fallen so low that it can fall no lower, it is impossible to get any more motive power out of it. But in chemistry it is not universally understood. Intelligent men still speak of the power or energy *locked up* in every drop of water, when they ought to speak of the energy that *was given out* millions of years ago, when the water was formed by the combination of oxygen and hydrogen; and to speak of it as energy or motive power, is the same kind of error that it would be to speak of the pressure of the ocean on its bed as if any motive power were due to it. Water is burnt hydrogen, and hydrogen, or any other combustible, will not burn again after being once burned. A story is told, and is not at all too good to be true, of an iron-master who had learned enough of chemistry to know that water is composed of a combustible substance and a supporter of combustion: he inferred that it must have the properties of both its constituents, and tried the experiment of blowing a furnace with steam instead of air; but of course he only blew it out.

such a compound is decomposed back into its elements (as, for instance, when water is decomposed by an electric current) a quantity of energy, equal to that which was given out in its formation, is taken up again and becomes potential in the elements.

Compounds that take up Energy in their formation.—But there are compounds which have the exactly opposite relation to energy. In their formation energy is not given out but taken up, and when they are decomposed, the energy which became potential in their formation again becomes actual, and is given back in the form of heat. Peroxide of hydrogen is one of these; it is easily decomposed into water and oxygen, with disengagement of heat. Nitrous oxide belongs to this class, and probably also gun-cotton, nitro-glycerine, and the fulminating salts.

Excepting peroxide of hydrogen, all the compounds here named are compounds of nitrogen. The compounds of nitrogen are in general remarkable for their great chemical activity, while uncombined nitrogen is equally remarkable for its inertness. This has often been mentioned as something surprising; but most probably the inertness of uncombined nitrogen is in some way connected with the capacity of its compounds for taking up large charges of energy in the act of their formation.

It is obvious that the energy which is taken up in the formation of these compounds must have some source:—it cannot be created out of nothing in the act of their formation. Such compounds as these are never formed by the spontaneous combination of their elements as in combustion, but are results of complex processes; and the energy which they take up must be given out by other chemical compositions or decompositions forming part of the same process.

Organic Compounds belong to this class.—After these general observations respecting energy, we are in a position to consider the special relations of energy to the vital process.

There is good reason for believing that the most important organic compounds belong to that class of compounds which take up energy in the act of their formation. "It has been shown by Berthelot that by the hydration and dehydration of organic substances heat results. Thus sugar, starch, and fatty matter by decomposition give rise to increased development of heat; and when albuminoid matters are hydrated and decomposed, or dehydrated and caused to enter into composition, heat is set free, altogether independently of the process of oxydation."[1] These facts appear to prove that organic compounds, as well as such compounds as peroxide of hydrogen and nitrous oxide, contain a charge of energy which is due to their chemical constitution, and part with it when that constitution is subverted. It is impossible to doubt that this fact must stand in some important relation to the dynamics of the living organism.

Opposite relations of Vegetables and Animals to Matter.—We have seen in the preceding chapter that vegetables form the characteristically organic compounds; these serve as the food of animals, and, after undergoing an assimilative change in their nutritive systems, become part of their tissues. The organic compounds afterwards undergo a change, chiefly consisting in oxidation, which totally alters their chemical character, and makes them incapable of any longer forming part of a living tissue, so that they are cast out as waste materials.

Animals feed on vegetables, and vegetables feed on inorganic matter. That is to say, vegetables derive the carbon, hydrogen, nitrogen, and oxygen, which are found variously combined in their substance, from the carbonic acid, water, and ammonia of the atmosphere. The assimilation to which an animal subjects its vegetable food before that food can become part of its tissues, though of course it is an all-important process for the purposes of life, effects but a very slight chemical change; and an exactly similar assimilative process is necessary when the food consists of the flesh of other animals. So that we may broadly say,

[1] Beale's edition of Todd and Bowman's *Physiology*, p. 137.

that vegetables form the organic compounds out of the materials of the inorganic world, and animals give them back to the inorganic world again, in the form of waste material. Thus the relations of vegetables and of animals to matter are opposite.

Opposite relations of Vegetables and Animals to Energy.—Their relations to energy are also opposite. As already stated, the change that converts the substance of animal tissues into waste material essentially consists in oxidation, and oxidation always produces heat, or some equivalent form of energy. The chemical transformation either of the food, or of the substance of the tissues that is passing away in waste, is the source of animal heat, and of the mechanical energy of animal motion. Animals thus *give out* energy to the organic world. The dynamical function of vegetables is the opposite of this. We have seen that they decompose water and carbonic acid. In the decomposition of these, or any other products of combustion, a quantity of energy is taken up and becomes potential, exactly equal to that which was given out and became actual when that product was formed by combustion;—this is true whether the decomposition is effected by an inorganic process, or in the organism of a living vegetable;—and we have seen that in the formation of organic compounds, a further, though much smaller, charge of energy is taken up. Thus, whatever quantity of energy *becomes actual*, as heat, from the chemical transformation of the substance or the food of an animal, and is *given out* in the radiation from the skin and in the heated breath, the same energy must have *become potential*, and been *taken up*, when the hydrogen and carbon of that animal's food were separated from the carbonic acid and water of the atmosphere by the vegetables on which it has fed; or, in the case of a carnivorous animal, by the vegetables on which its prey has fed.

Dynamic action of Vegetables in decomposing Carbonic Acid.—But in what form was the energy before it assumed this

potential form? For vegetables cannot create energy out of nothing, any more than can animals or machines.

It was in the form of radiance.[1] It is usually said that the leaves and other green parts of vegetables decompose carbonic acid *under the stimulus* of light. But this is an inaccurate expression: as well might we say that the decomposing cell in electro-chemical experiments decomposes water *under the stimulus* of the electric current. The decomposing cell and the green leaf alike are only the apparatus where the decomposition takes place; the agent of the electric decomposition is the electric current, and the agent of the decomposition of the carbonic acid (and doubtless water also) that is decomposed by the green leaf, is the sun's radiance that falls on it. As the actual energy of the electric current is, in the act of decomposing water, transformed into the potential energy due to the mutual affinity of the separated oxygen and hydrogen, so the actual energy of the radiance that falls on a leaf is, in the act of decomposing carbonic acid, transformed into the potential energy due to the mutual affinity of the separated oxygen and carbon.

Thus we see that vegetables transform energy from the actual state of radiance to the potential state due to the affinity of separated elements, and animals transform it back again into the actual state, either as heat or as energy of muscular motion. In other words, vegetables take up both matter and energy from the inorganic world, and the animals that feed on the vegetables give back the matter and the energy to the inorganic world again. All animal energy is ultimately derived from the sunbeams that fall on the vegetables from which the animals obtain their food.

It is only in the light that vegetables decompose carbonic acid. In the dark, and probably at all times, they produce carbonic acid by the slow oxidation of their substance; and in consequence of this, their temperature, as ascertained by

[1] By radiance I mean light and radiant heat. There is no physical difference between them; light consists of those rays of radiant heat to which the retina is sensitive.

Dutrochet, is, during life, slightly higher than that of the surrounding air.[1] This slow oxidation is a process of respiration, essentially similar to that of animals; and respiration is a slow combustion.

Vegetables have a double, Animals only a single, relation to the Inorganic World.—Vegetables have thus a double relation to both matter and energy: they take up matter from the inorganic world by decomposing carbonic acid and fixing carbon, and in the same act take up energy which becomes potential in the separated carbon: and they give back matter to the inorganic world in respiration; which process restores the carbon as carbonic acid, and in the same act gives back energy in the form of the heat of respiration. Animals, on the contrary, have no power of acquiring either matter or energy from the inorganic world; but animals give them back by a much more energetic respiration than that of vegetables.

Animal Motor Energy is derived from the Oxidation of the Food.—Animals also restore to the inorganic world considerable quantities of energy in the motor form, through the muscles. Whatever energy is given out by an organism, whether as heat in respiration, as motor energy through the muscles, or in any other way, must be obtained by the chemical transformation, chiefly the oxidation, of its food. I say *chiefly* the oxidation, because we have seen[2] that the organic compounds give out heat in being decomposed, and no doubt animals obtain energy in this way from the decomposition of their food.

All Organisms transform both Matter and Energy.—It is a familiar truth that every living organism by its nutritive system is constantly transforming matter, and it is equally true that every living organism is constantly transforming energy. Any account of the vital process contains only half the truth

[1] Carpenter's *Comparative Physiology*, 3rd edit., p. 846. It is from this edition I shall always quote.

[2] P. 15.

unless it gives as much emphasis to the fact of the transformation of energy by the action of the organism, as to the fact of the transformation of matter. In the present state of science, indeed, this is almost self-evident; but it could not be clearly seen until the laws of the conservation of energy, and of the transformations of energy, were understood.

It is now time to consider more precisely the laws of these transformations.

We have seen that energy is taken up in the formation of organic compounds. It appears likely that this energy is directly obtained and appropriated by the plant from the radiance which falls on its leaves; but it may be also in part derived from the slow combustion of carbon.

Energy of Organization.—But in addition to the energy thus taken up chemically, it appears probable that energy is taken up in the process of organization and development. On this subject I am not aware that any precise determinations have been made: we only infer that energy is probably so taken up from the fact that there appears to be a demand for energy, in the form of heat, during every process of organic development; but in the absence of precise experiments we cannot assert with certainty for what purpose the heat is required. Heat, as already stated, appears to be a concomitant of vegetable as well as of animal life generally; and it is produced in unusual abundance in the act of flowering. The flower of the *Arum cordifolium* has been found to have a temperature 20° above that of the surrounding air.[1] Heat is also produced in the germination of the seed. Its source in these cases is oxidation: this is proved, if proof were needed, by the production of carbonic acid: and its purpose, no doubt, is in some way to promote the transformations that take place in the acts of flowering and germination. Animal development also depends in some way on temperature: this, as everyone knows, is true of the

[1] Stated in Carpenter's *Comparative Physiology* (p. 846), on the authority of Adolphe Brogniart. I presume the degrees are centigrade. 20° C. = 36° F.

hatching of eggs, and it is equally true of the final metamorphosis of the insect.[1] It is a case of the same law, that the triton, or water-newt, which has a remarkable power of reproducing lost limbs, can only do so at a higher temperature than that which is necessary for its health.[2] It is scarcely possible to doubt that, in every act of organic development, there is some transformation of energy, though we cannot yet say what transformation. Probably, as already suggested, a charge of energy is taken up and becomes potential in the act of unorganized material acquiring organization.[3]

Energy of Life depends on Supply of Oxygen.—Vital processes go on with the greatest energy where oxidation is most rapid. This is partly, no doubt, because oxidation yields the necessary supply of heat and other forms of energy: partly also, because the waste, or what may be called the wearing out, of the tissues of the organism goes on most rapidly where vital processes are most energetic: and this will soon be checked if there is not a supply of oxygen to transform the organic compounds into freely soluble compounds, which can be easily removed from the system. It is, no doubt, in consequence of these two causes that air-breathing animals and air-breathing plants are in general of much higher organization than water-breathing ones, and that air-breathing animals have a more active and energetic life; for air contains a much more abundant supply of free oxygen than water. Warm-blooded animals, which stand at the head of the whole animal kingdom, are without exception air-breathers: and, among vegetables, most of the water-breathing kinds are flowerless, and, as such, inferior to the flowering ones in organization. It is no exception to this, but rather a confirmation of it, that many flowering

[1] Carpenter's *Comparative Physiology*, p. 849.

[2] *Ibid.* p. 65, quoted from Mr. Higginbottom: Proceedings of Royal Society, 18th March, 1847.

[3] See chap. i. of Carpenter's *Human Physiology*, eighth edition. It is from this edition I shall always quote.

plants, such as water-lilies, though rooted under water, raise their flowers and part of their leaves into the air, in order no doubt to enable them to obtain the oxygen they need. It belongs to this class of facts that there are many instances, among both insects and batrachians (frogs, newts, and similar animals), in which the larva is a water-breather and the perfect form an air-breather ; but not a single instance, I believe, of the converse: for the perfect form in those two classes is always more highly organized than the larva. It is indeed the general law of animal metamorphosis, though subject to some remarkable exceptions, that the mature form is more highly organized than the larva.

Vital Energy.—We have seen that energy is taken up in the formation of organic compounds, and that probably a further charge of energy is taken up in the formation and development of structure out of those compounds. There appears to be very strong evidence of the existence of a third form of energy, which is stored by the nervo-muscular system of animals, and probably exists in greater or less quantity in all living organisms whatever. But before stating the evidence for this, it is necessary to make some general remarks on the motions and motor organs of organisms generally.

The Nutritive System transforms Matter : the Nervo-muscular transforms Energy.—The nutritive system of both animals and vegetables, using the expression in its widest sense to denote the system of organs of the vegetative or merely organic life, may be described as an apparatus for the transformation of matter. In addition to this, all animals except the lowest have a nervo-muscular system, which may with equal accuracy be described as an apparatus for the transformation of energy, chiefly though not exclusively into the motor form.

All Organisms produce Motion.—Organisms restore to the inorganic world the energy which they have received from

it through the vegetable kingdom, chiefly in the two forms of heat and motion. We have seen that vegetables are producers of heat, like animals, though in a much less degree: and it appears to be equally true that all organisms whatever are producers of motion. It needs no proof that this is true of animals, even those which are rooted, like corals and sponges, for they have tentacles or cilia, which they move. It appears to be also true of vegetables. The motion of the germs of sea-weeds is so active that they have often been mistaken for microscopic animals. And some degree of motive power appears to be universal in the protoplasm of both animals and vegetables. Protoplasm, or germinal matter, is a gelatinous substance, unorganized but capable of organization, which is found in small masses in all parts of the living organism, and most abundantly where growth is most rapid.

Motive Powers of Vegetables.—"The substance called protoplasm exhibits changes of form and other movements, which cannot be explained by any physical property, or by any extraneous influences. These movements are most remarkably shown at times in the spaces of young cellular tissue. The movement termed rotation, or gyration, which is often seen in the contents of young cells, and which, in some form or other, is probably of general occurrence, may depend on the contractility[1] of protoplasm. They are said by those who have studied them to present a close resemblance to those of Amœba[2] and its allies. No one has yet shown a distinction of importance between protoplasm of the vegetable and sarcode of the animal kingdom. But there are other movements in plants, the cause of which is less equivocal. Such movements are not confined to the lowest plants, as the Oscillatoriæ, but are met with among the most highly organized members of the vegetable kingdom.

[1] *Contractility* is not a good word. What is meant is only the tendency to spontaneous motion.

[2] The amœba is an animal, and one of the simplest known, being a minute gelatinous mass without structure.

The movements of sensitive plants, various species of Mimosa, of *Dionæa muscipula*,[1] of certain tropical species of Desmodium, of the stamens of Barberry, &c., can be referred only to vital contractility of certain of their tissues. Whatever obscurity may hang over these, let it be remarked that there is the same evidence of the nature of this vital contractility in plants as in animals. It is dependent on life, and not, like any physical property, retained so long as the structure itself is not destroyed. So, also, these movements either occur spontaneously, or may be excited by various stimuli—touch, for example. If those motions depended upon elasticity, or hygroscopic changes, or any other physical cause which elsewhere operates, how could stimuli act to produce them? Moreover, they appear to be governed by the same laws that regulate their action in the animal kingdom. Their energy varies with the vigour of the plant. Excessive exercise produces exhaustion, but the power is restored during subsequent repose. This evidence, thus clear and satisfactory, receives a remarkable and most interesting confirmation from the effects produced by the vapour of chloroform."[2]

Since the foregoing passage was written, Darwin has shown, in his two most valuable works on Climbing Plants and on Insectivorous Plants, that powers of motion are much more common in the vegetable kingdom than had been believed.

Production of Light and Electricity by Animals.—Heat and motion are not, however, the only forms of energy that organisms give out. The glow-worm, and some other insects, have a special apparatus for the production of light, and many of the simpler marine animals are luminous.[3] And the torpedo, the

[1] Familiarly called "Venus's fly-trap," from the way in which the leaves spontaneously close on flies and crush them.

[2] From a lecture *On Motion in Plants and Animals*, delivered at the Royal Institution on 14th March, 1862, by William Scovell Savory, F.R.S. See also Beale's edition of Todd and Bowman's, *Physiology*, pp. 33, 99.

[3] Among the medusæ and mollusca the luminosity appears to be due to a phosphorescent secretion, and if so, it cannot be regarded as a vital phenomenon;

gymnotus, and a few other fishes have a special apparatus for the production of electricity at will.

Energy stored by the Organism illustrated by the Hydraulic Accumulator.—We have seen that the energy which is given out by animals as motion or heat, or in any other form, is derived from the oxidation of their food: just as the energy given out by a steam-engine is derived from the oxidation of the coals in the furnace. It is now time to consider the question which has been already suggested, whether, besides transforming and giving out energy, they have the power of storing it in a peculiar form. In other words, whether the energy that animals part with in muscular action is obtained, by these chemical actions, at the very moment when it is wanted; or whether there is a stock of energy constantly kept in the body, in a peculiar form distinct from any chemical form, and capable of being drawn on for conversion into muscular motive power when wanted? This distinction may not be quite intelligible to readers who are not familiar with the subject of the transformations of energy; but it may be illustrated by the following example. When a steam-engine is at work in the usual way, the motive power that it exerts is all produced, by the combustion of the fuel in the furnace, at the very moment when it is wanted. But if the steam-engine works in connection with one of Armstrong's hydraulic accumulators, energy, or motive power, is stored in the accumulator; so that work may continue to be done for some time after the steam is turned off or the fire put out. The question is this: Does the animal organism resemble the steam-engine working without an accumulator, which can only transform the motive power which is at that very instant liberated in the chemical process of combustion? or does it rather resemble the steam-engine working with an accumulator, which stores motive power in a form that can be drawn on when wanted?

but among the marine annelids, or worms, it does not appear in a steady glow, but in flashes or scintillations, which are produced by irritating the animal; and some of the smaller crustacea also emit light in little flashes.—(Carpenter's *Comparative Physiology*, p. 841.)

We have what seems very strong if not conclusive evidence that the latter is the fact—that the living animal contains a variable quantity of a peculiar form of energy, which is capable of being transformed when needed either into heat or into muscular motive power. I propose to call this vital energy; and I regard it as a distinct form of energy, like heat, electricity, magnetism, or the energy of motion. An animal, regarded as a motor apparatus, may thus be compared to a steam-engine doing work with the assistance of an accumulator. In both, energy is being constantly obtained by the combustion of carbon (for the oxidation that goes on in the lungs and throughout the body is combustion, differing from that of a furnace only in being slower); in both, the energy, when not at the moment wanted to do work, passes into the potential form. In the steam-engine it passes into the potential energy due to the raised weight of the accumulator; in the animal, into potential vital energy. And in both, it is capable of being used as motive power when wanted to do work.

Vital Energy does not explain Life.—It should be observed that this theory about vital energy is not offered as an attempt to solve the mystery of life. Life can no more be explained by the laws of vital dynamics than by the chemistry of protoplasm.

We go on with the evidence for the existence of vital energy stored up in a distinct form.

Muscular Heat in Healthy Action.—Muscular action causes a rise of temperature in the acting muscle, and the rise is greater when the muscle is strained in a dead pull against something unyielding, than when it raises a weight.[1] This is a very interesting case of the equivalence of different kinds of energy: the muscular energy which raises a weight is transformed into

[1] Carpenter's *Human Physiology*, p. 868. The reason given in the text for the last-mentioned fact seems much more satisfactory than Dr. Carpenter's, which is that "during the active alternate contraction and elongation of the fibres (when they contract so as to do work) the circulation through the vessels is more rapid, so that the heat locally produced is carried off by the blood."

the potential energy due to the raised weight, and if the same muscular energy is expended without being able to raise a weight or do other external work, it is transformed into heat. Normally, the increase of temperature is not more than 1° Fahr.,[1] and it is not perhaps incredible that this should be due to the more rapid chemical action that goes on in muscle when it is in activity than when in repose. The heightening of chemical action in muscles during activity is proved by the fact that lactic acid, which is a product of their oxidation, is found in the muscles of animals that have been violently contracted, though it is not found in muscles in their normal state.[2]

Abnormal Production of Heat in Disease.—But though chemical action may account for a rise of temperature in muscle to the extent of 1° Fahr., it appears altogether inadequate to account for a rise of the temperature of the body to 110¾° Fahr., which is more than twelve degrees above its normal level; and this has been observed in the convulsions of tetanus.[3] No conceivable increase in the rate of chemical action would produce such a rise of temperature as this; and it most probably has been caused by the transformation of a portion of the stock of vital energy into heat.

Heat produced at Death.—Another case of increased production of animal heat which cannot be due to any increase in the rate of oxidation or of any other chemical process, has been observed in patients dying of yellow fever, when the temperature of the body rose to the extent of 5° Fahr. in the first ten minutes after death.[4] If proof is needed that the heat could not be from any chemical source, it is afforded by the fact that the capillary circulation in those cases continued for an appreciable time after death, showing that no great change had taken place in the tissues; and this extraordinary production of heat can, so far as appears, only be explained by supposing that

[1] Carpenter's *Human Physiology*, p. 558.
[2] *Ibid.*, p. 866.
[3] *Ibid.*, p. 561.
[4] *Ibid.*, p. 562.

the vital energy of the body was transformed into heat in the act of dying. This however is only an extreme case of the fact that muscles rise in temperature when they enter into the state of *rigor mortis*, or the stiffening which follows death and precedes putrefaction;[1] and the belief that this is due to the transformation of vital energy seems the more probable, as there is some reason for believing that the chemical actions which take place in *rigor mortis* are only an extreme continuation of those in ordinary muscular contraction.[2]

An experiment by John Hunter is recorded which is probably a case of the same kind as the preceding. He put a bottle containing leeches into a freezing mixture: a thermometer among the leeches sank to 31° Fahr.: it afterwards rose to 32°, and the leeches froze.[3] The rising of the thermometer when the leeches froze seems, when taken along with the other facts mentioned above, to show that their vital energy must have been transformed into heat.

Motor Energy produced at Death.—In other cases the vital energy is transformed at death into motor energy. This is probably the explanation of those convulsive struggles which often accompany death, and are frequently attributed to pain, though this is not by any means invariably the case.

Heat produced by Animals during Starvation.—Another proof that animals have a stock of vital energy to draw on for conversion into heat when needed is afforded by the fact that starving animals appear to be able for some days to produce heat at a greater rate than the chemical actions of the organism could supply. "It has been experimentally found that in the ordinary life of an adult mammal, the quantity of food necessary to keep the body in its normal condition is *nearly twice* that which would be required to supply the waste of the organism,

[1] Gamgee's translation of Hermann's *Elements of Human Physiology*, p. 269.
[2] *Ibid.*, p. 252. See note A at end of Chapter.
[3] Carpenter's *Comparative Physiology*, p. 848.

as measured by the total amount of excreta when food is withheld." [1] In other words, they live on an expenditure of *little more than half* the material, as shown by the waste of the body, than is consumed by well-fed animals ; and while doing so they keep up their temperature nearly at its normal level. I do not see any possible way of doing this except by drawing on their stock of vital energy for conversion into heat. At last the temperature rapidly falls, and the depression of temperature is the immediate cause of death. It is a familiar fact that starving animals lose substance, and it is certain that the oxidation of the substance that disappears helps to keep up the temperature ; but it now appears that more heat is produced than this is sufficient to account for.

Experiments on the Nervo-Muscular System of Animals.—The strongest proof of the existence of vital energy in a distinct form is, however, derived from experiments on the nervo-muscular system of animals. It has been observed by Sir Benjamin Brodie, and by others who have repeated his experiments, that when the spinal cord of a rabbit or other animal is divided in the neck, and the action of the lungs (which otherwise would cease in consequence of the paralysis of the nerves that supply their muscles) continued artificially, so as to produce the normal quantity of carbonic acid, the temperature of the body falls.[2] Now, we know that a definite quantity of actual energy is due to the formation of a definite quantity of carbonic acid by oxidation, whether in the living organism or in a furnace : in the experiment in question this energy does not

[1] Dr. Carpenter, *Quarterly Journal of Science*, 1864, p. 265. It ought to be mentioned that Dr. Carpenter interprets this fact differently, and in a way which I do not quite understand.

[2] Carpenter's *Human Physiology*, p. 572. In some cases, however, the effect is to raise the temperature. "This fact, however, appears to be sufficiently explained by the relaxation of the walls of the smaller arteries, producing a state resembling a permanent blush, and the consequent increase in the afflux of blood to the part, which has been shown by Dr. Aug. Waller to result from this operation." *Ibid.*, p. 574.

appear as heat; what then becomes of it? I think the only possible interpretation of this experiment is, that the energy which becomes actual in the formation of carbonic acid by oxidation in the body, is in part transformed, not at once into heat, but into vital energy, which the nervous system is capable of afterwards transforming into heat. Consequently, when the nervous system is in great part paralysed by cutting the spinal cord, the production of vital energy, which is a function of the whole organism, goes on as before; but its transformation into heat, which is a function specially of the nervous system, is hindered.

There is, moreover, another experiment, which is the exact correlative of Sir Benjamin Brodie's, and shows us what has become of the energy in question. Brown-Séquard weighted the hind-legs of living frogs, and thus ascertained what weight they were capable of raising when the muscles of the legs were excited to contract by pinching the toes: this weight was taken as the measure of the contractile force of the muscles. He then divided the spinal cords of the frogs, and found that twenty-four hours after the operation the force of their muscles, as measured by the weight they were able to raise, was twice as great as when they were uninjured.[1] Thus, when the spinal cord is severed, we see by the one experiment that the temperature falls, and by the other that the mechanical force of the muscles is increased. The two taken together seem to afford conclusive proof that in an animal with divided spinal cord the vital energy accumulates in the muscles; while in an animal with uninjured nervous system, nervous influence determines the transformation of the vital energy partly into heat and partly into motor energy, and does not permit it to accumulate in so great a degree.

Heat-producing Power of the Nervous System.—This, however, is only one of the instances which prove the nervous

[1] Dr. Norris's "Report on Muscular Irritability" (British Association, Nottingham, 1866).

system to have the power of transforming vital energy into heat. Valentin has observed a rise of $1\frac{1}{4}$ centigrade in the temperature of the sciatic plexus of a frog, by mechanical or electrical irritation of its spinal cord.[1] Conversely, a lowering of nervous action has a tendency to depress the temperature. The paralysed limb of a patient is usually somewhat colder than the healthy one. And a curious instance is on record, in which a wound of the wrist, which must have affected a nerve, produced partial insensibility in the forefinger, and lowered its temperature 10° Fahr. below that of the thumb.[2]

The Source of Animal Heat is Chemical.—This comparatively new doctrine of the heat-producing function of the nerves in no degree contradicts the older and perfectly established doctrine of the chemical origin of animal heat. The nerves cannot create energy, nor bring it into the organism: they can only store it and transform it.

Fick and Wislicenus on Muscular Work.—The observations of Fick and Wislicenus on the work done in muscular exertion[3] appear to prove that the work which may be done, and is habitually done, by the muscles, is much greater than can possibly be due to their oxidation during the period of activity. This is an independent confirmation of the theory that the nervo-muscular system not only transforms, but stores energy.

Muscles Charged with Energy are Relaxed.—It is to be observed that a muscle containing a charge of energy is elongated and relaxed, and the contracted state of the muscle is that in which the energy has been parted with.[4] This distinction is very important, and by no means obvious.

1 *Medico-Chirurgical Review*, January 1864.

2 Jon. Hutchinson, *Med. Times and Gazette*, 1863, vol. ii., p. 197, quoted by Carpenter.

3 *Philosophical Magazine*, June 1866.

4 This, I believe, was first clearly stated by Dr. Radcliffe. See Carpenter's *Human Physiology*, p. 866, note.

It is opposite to that which obtains in an elastic body, such as an indiarubber cord; for the indiarubber contains a charge of energy while it is strained, but none while it is relaxed.

Restoration of Vital Energy in Sleep.—The vital energy in the body is of course fluctuating in quantity: it is expended by muscular or nervous exertion, and restored again during rest, and especially during sleep. The instinct is common among warm-blooded animals of keeping themselves from cold during sleep; and this may be in order to prevent the energy which they need for muscular exertion from being used in merely keeping up the temperature of the body.[1]

Hybernating Animals.—It has long been known that the temperature of hybernating animals sinks far below that which they maintain while awake. This is obviously for the purpose of economising vital energy, which would otherwise be expended in warming the body when warmth is not needed: and it has been lately asserted that the marmot, when it awakes out of its winter sleep, has a wonderful power of raising its temperature—transforming itself, in fact, from a cold-blooded into a warm-blooded animal—without drawing on any evident source for its supply of heat. Horvath observed one, the body of which was cooled down to 35° Fahr. when asleep, and two hours and a half after waking its temperature had risen to 59°, without any corresponding increase in the activity of either the animal's respiration or its muscles. It seems impossible to account for this, except by the hypothesis of a store of energy in a distinct vital and not chemical form.[2]

Buoyancy and Fatigue.—Abundance of vital energy is probably the cause of that feeling of buoyancy which makes action more

[1] See note B at end of Chapter.

[2] Carpenter's *Human Physiology*, p. 560, note. He says:—"The cause of this remarkable elevation of temperature is, according to Horvath, scarcely explicable on the ordinary chemical theory of calorification."

agreeable than rest; and deficiency of it is probably the cause of the sensation of fatigue. And possibly the immediate cause of death by fatigue may in some cases be the want of sufficient vital energy in the system to supply motive power for the work of the heart and lungs.

Generality of the Law of Fatigue.—The law that expenditure of vital energy causes fatigue is very general among organisms. It is well known that the gymnotus, or electric eel, becomes fatigued by repeated discharges. We have seen that with sensitive plants, like the mimosa, "excessive exercise produces exhaustion, but the power is restored during repose."[1] And the cut-off legs of a frog, when excited to kick by the stimulus of an electric current, gradually relax the force of their kicks, but recover when laid aside for some time. Some transformation of energy must take place during their recovery from fatigue; but perhaps this is only what is due to the oxidation of the muscular tissues.

Relation of Muscular Contraction to Electric Stimulus.—It is most important to observe that when, as in the case just mentioned, muscle is excited to contract by an electric current or shock, the electricity acts only as a stimulus;—though it is itself a form of energy, it does not supply energy to the muscle, but only determines the transformation of part of the energy which the muscle already possesses.[2] Animals are able to assimilate energy—in other words, to transform it into the vital form so as to be used for the purposes of their life—only when it is supplied by the oxidation (or other chemical transformation[3]) of their food.

The Nature of Vital Energy is Inexplicable.—What is there in the organism to represent vital energy? Heat and radiance consist in motion: magnetism and electricity,

[1] P. 23.

[2] See Dr. Richardson on the resuscitation of drowning animals, *Nature*, August 3, 1876, p. 289.

[3] See p. 15.

probably, in molecular tensions; but in what similar function does vital energy consist? This question must perhaps for ever remain unanswered; but this is no reason for questioning the existence of vital energy in a distinct form; the chemical forms of energy are equally inexplicable.

Assimilation of Energy.—We may now state, with very strong probability, that the relation of organisms to energy is parallel to their relation to matter. As an organism is constantly assimilating matter from without into its own substance, so it is constantly acquiring energy from without and transforming it into vital energy. This process may be called the assimilation of energy;—energy, like matter, is transformed by the action of the organism into the peculiar form which the organism needs;—this is the definition of assimilation. And as an organism is constantly parting with matter, which undergoes chemical transformation that unfits it for continuing any longer to form part of the organism, so it is constantly parting with energy, which is transformed into what may be called inorganic forms; that is to say, forms which can exist independently of vital agency, generally into heat or motion: in the case of electric fishes, into electricity; in the case of luminous insects, into light.

We may consequently make the following general statement:—

General Definition of Life.—An organism consists of a mass of peculiar chemical compounds of high complexity, and contains a charge of a peculiar kind of energy. It is constantly transforming both matter and energy, by assimilation, into these peculiar forms, and is as constantly parting with matter and energy, which are transformed into forms which are no longer capable of remaining in the organism. These relations of the organism to mattter and energy constitute the differentia of life.

NOTE A.

NATURE OF VITAL ENERGY.

Question as to the Nature of Vital Energy.—In what form is the energy held which has been assimilated by the living organism? This question is as yet impossible to answer with any certainty.

Dr. Radcliffe's *Electric Theory of Muscular Action.*—Dr. Radcliffe has lately published a most interesting work on *The Dynamics of Nerve and Muscle*, in which he endeavours to show that the energy stored in relaxed muscle is not any peculiar form of energy, but simply an electric charge. I cannot, however, think his reasoning at all satisfactory.

Hermann's *Chemical Theory of Muscular Action.*—Hermann maintains as highly probable, that in muscular contraction there is a chemical change in the almost liquid substance contained within the elongated muscle-cells;—this chemical change is accompanied by a liberation of energy, which supplies the motive power of the muscle. This change does not consist in oxidation, and the liberation of energy thus occurring is not analogous to the liberation of energy which occurs in oxidation and produces heat;—it is a case of the liberation of energy which occurs in the decomposition of certain compounds, especially compounds of nitrogen.[1] The chief argument in favour of this view is that rigor mortis, or the stiffening of muscle that follows death, is unquestionably accompanied by a chemical change, which is manifested in the coagulation of the fluids: and rigor mortis is shown to be an extreme continuation of ordinary muscular action, by the facts that ordinary muscular action and rigor mortis are both accompanied by contraction and by heat, and that "an excised muscle yields the same amount of carbonic acid whether it enters at once into rigor or has previously generated carbonic acid by contraction; therefore, the more carbonic acid is produced by contraction, the less does the muscle evolve on entering afterwards into rigor. The same relation seems to exist in the case of the lactic acid—at least, a muscle which has been active in the body on entering into rigor after excision, produces less acid than one which has remained at rest."[2]

It is not improbable that every muscular action is accompanied by some chemical change in the very complex and unstable compounds that constitute muscular substance: and it is very probable that these compounds, which are at once organic compounds and nitrogen compounds, give out energy during such changes. Hermann's chemical theory of muscular action therefore

[1] See pp. 14, 15.

[2] Gamgee's translation of Hermann's *Human Physiology*, p. 252. See the whole of the 8th chapter.

appears likely enough to be true to a certain extent, but it is not certain that it will account for all the facts. If Hermann is right, there is no vital energy in any separate form, and what in the foregoing chapter has been described as vital energy, is really the chemical energy of the fluid substance of the muscles ;—and this, even if sufficient to account for the facts of muscular contraction and heat, appears not to account for the heat produced by starving animals,[1] nor, perhaps, for the connection which we have seen to exist between the activities of the nervous system and the distribution of heat through the body.[2] Moreover, it is difficult to believe that a rise in temperature of 12° Fahr. could be produced by a chemical change essentially consisting in the coagulation of myosin, which is an albuminous substance. Least of all will Hermann's theory account for the temperature phenomena of Horvath's marmot.[3]

The facts, on the whole, appear to show that animals have a stock of vital energy to draw on, independently of any chemical energy ;—and if this is true of animals, it is probably true, in a less degree, of vegetables also.

NOTE B.

EFFECT OF ALCOHOL ON BODILY TEMPERATURES.

The relation between the storing of energy in the organism and the production of heat, may be illustrated by the following facts :—

"Drs. Ringer and Rickards have shown that, excepting in those who are accustomed to its use, the ingestion of alcohol in considerable doses causes a remarkable diminution of temperature, amounting in some cases to about 3° Fahr. In rabbits, the injection of alcohol into the rectum caused a depression of the animal heat amounting to about 15° Fahr."[4]

Facts of this kind have often been quoted to prove that the effect of alcohol is depressing. It would, however, be incredible that the sensations of mankind should be wrong in affirming that the immediate effect of alcoholic stimulants is invigorating : and the facts in question do not really prove this. The truth to which they point may be, and probably is, that the effect of alcohol is to prevent the transformation of vital energy into heat, and to retain it for use in the muscles as motive power. This hypothesis, if it ought not to be called a certainty, explains the invigorating effect of alcoholic drinks in moderate doses ; and it reconciles this with another fact which seems to be well attested, namely that their use in even small quantities is injurious in very intense cold like that of the Arctic regions, where the first necessity is to keep up the temperature of the body.

[1] See p. 27. [2] See p. 30. [3] See p. 31.
[4] Carpenter's *Human Physiology*, p. 559.

CHAPTER III.

THE ORIGIN OF LIFE.

Question whether Life can be evolved from Matter.—We have seen in the preeeding ehapter that life appears to eonsist in the peeuliar relations of the organism, or living being, to matter and energy. This however does not solve the questions, whether the peeuliar vital prineiple is a resultant from the powers of dead matter, and whether life ean be produeed from inorganie matter by any physieo-ehemical proeess.

Experimental evidence seems in the negative.—The latter is purely a question for experiment. A great number of experiments have been tried on this subjeet of late years, and it appears to be the opinion of all the highest authorities, ineluding Pasteur, Dr. Beale, and Professor Huxley—the last of whom, at least, is not a prejudieed witness against them—that they do not bring us one step nearer to the origin of life, and have no tendeney to disprove the prevailing belief that all living beings, however minute and lowly, down to *Bacterium* and *Protocoecus*, are deseended from living parents: and that where they seem to appear spontaneously, they are really produeed from pre-existing germs, which, by reason of their minuteness and their tenaeity of life, have baffled the endeavour of the experimenter to exelude them.

Sueh evidence cannot be conclusive cither way.—Experimental evidence of this kind, however, cannot be absolutely conelusive.

It is proverbially difficult to prove a negative; and we must accept a negative as proved before we adopt for certain either a positive or a negative conclusion on this subject. No finite number of experimental failures to produce life out of dead matter by a physico-chemical process would be sufficient to disprove the possibility of such production under some rare conjuncture of favouring circumstances: and, on the other hand, supposing such experiments to be attended with perfect apparent success, it would still be scarcely possible to prove that the result was not due to pre-existing germs, which the utmost skill of the experimenter had failed to exclude.

All alleged Chemical Production of Life is from Organic Substances.—Moreover, in all cases where it is alleged that living beings can be produced from dead matter, the matter is not inorganic, but dead organic matter; and we have seen that no chemistry except that of a living organism, whether vegetable or animal, appears to be able to produce the characteristically organic compounds. If, then, it is possible for dead organic matter to be made to live by a chemical process, this will not prove that the same may be done with inorganic matter, and does not bring us any nearer to the beginning of life.

Those who maintain that the vital powers are only resultants from the physico-chemical ones, and fancy that they can "discern in matter the promise and potency of every form and quality of life," do so only by "crossing the boundary of the experimental evidence" in obedience to a supposed "intellectual necessity."[1] In other words, they believe that life must have been originally evolved from matter by a purely natural process, not on the strength of evidence or induction from evidence, but as a dogma of their scientific creed.

The Distinction between Living and Dead Matter appears to be

[1] The words marked "thus" are from Professor Tyndall's address to the British Association at Belfast in 1874.

perfectly Definite.—No gradation has been found, or appears possible, between living and inorganic being, like that which connects the animal kingdom with the vegetable. The resemblance of the simplest organisms to inorganic matter has been much exaggerated. All organisms grow by the assimilation of food: and there is nothing like this in inorganic nature.[1]

The Vital Principle and the "Watch-principle."—It is necessary to justify, or at least to show in what sense I use, the expression *vital principle*, which occurs in the first paragraph of this chapter. The question has sometimes been asked, as if it were a *reductio ad absurdum* of the hypothesis of a vital principle, whether an intelligent being, totally ignorant of machinery, on seeing a watch for the first time, would be logically justified in asserting a hypothetical "watch-principle" as the cause of so much of the construction and of the action of the watch as he was otherwise unable to explain. Let us suppose this being to be not a human savage, but a visitor from some other planet, or from the dwelling of the deities of Epicurus in

"The lucid interspace of world and world,"

and let us suppose he examines the watch as Huxley would examine a new living species, or as Tyndall would investigate a newly-discovered electric or magnetic phenomenon. He ascertains, by a comparison between the motion of its hands and that of the heavens, that its function is to mark the hours and minutes: he ascertains that the wheels work according to simple

[1] This is insisted on in Dr. Beale's works, as it deserves to be. I think, however, that he insists too much on the spontaneous motions of protoplasm or germinal matter as evidence of the absolute distinction of vital from physical properties. Some motions which are certainly not vital, are very strange, though easily explicable—those, for instance, which are produced by dropping alcohol on the surface of water. They are due to the capillary force of alcohol being less than that of water. In order to see them properly, a little lycopodium powder ought to be dusted over the water before dropping the alcohol. A bit of camphor floating on water shows somewhat similar motions, which are due to the formation of a solution of camphor in the water, and the capillary action between it and the rest of the water.

and perfectly intelligible mechanical laws, and are set in motion by the uncoiling of a spring: but as to the agency by which the watch has been constructed and the spring wound up, he ascertains only that brass and steel have no tendency to crystallize into the form of a watch, and that there is no power within the watch itself which can have wound up the spring. If, then, he provisionally gives the name of the "watch-principle" to the unknown agency by which the watch has been constructed and its spring wound up, this is not foolish, but logical and necessary. Now, how does our position with respect to living beings differ from that of our imaginary visitor with respect to the watch? It is true that we can see the development of the more transparent organisms under the microscope; but to see is not necessarily to understand: we are altogether ignorant of the nature of the agency that produces organisation and causes the vital functions to go on, and in our ignorance we provisionally name it the vital principle.

Huxley on "Aquosity."—Perhaps, however, this well-worn instance of the watch is not the best that could be adduced. Professor Huxley says on the same subject[1]:—"When hydrogen and oxygen are mixed in a certain proportion, *and an electric spark is passed through* them, they disappear, and a quantity of water equal to the sum of their weights appears in their place. There is not the slightest parity between the passive and active powers of the water and those of the oxygen and hydrogen which have given rise to it. At 32° Fahr. and far below that temperature, oxygen and hydrogen are elastic gaseous bodies whose particles tend to rush away from one another with great force. Water at the same temperature is a strong though brittle solid, whose particles tend to cohere into definite geometrical shapes, and sometimes build up frosty imitations of the most complex forms of vegetable foliage. Nevertheless, we call these and many other strange phenomena the properties of the water; and we do not

[1] "On the Physical Basis of Life," *Fortnightly Review*, February, 1869. The italics are mine.

hesitate to believe that in some way or another they result from the properties of the component elements of the water. We do not assume that a something called 'aquosity' entered into and took possession of the oxide of hydrogen as soon as it was formed, and then guided the aqueous particles to their places in the facets of the crystal or amongst the leaflets of the hoar-frost. On the contrary, we live in the hope and in the faith that by the advance of molecular physics we shall by and by be able to see our way as clearly from the constituents of water to the properties of water as we are now able to deduce the operations of a watch from the form of its parts and the manner in which they are put together. Is the case in any way changed when carbonic acid, water, and ammonia disappear, and in their place, *under the influence of pre-existing living protoplasm*, an equivalent weight of the matter of life makes its appearance? It is true that there is no sort of parity between the properties of the components and the properties of the resultant, but neither was there in the case of the water. It is also true that what I have spoken of as the influence of pre-existing matter is something quite unintelligible; but does any one quite comprehend the *modus operandi* of an electric spark which traverses a mixture of oxygen and hydrogen? What justification is there, then, for the assumption of the existence in the living matter of a something which has no representative or correlative in the not living matter which gave rise to it? What better philosophical status has 'vitality' than 'aquosity?'"

Reply.—Difference between Crystallization and Life.—I reply that the cases are not parallel. In order to account for the properties of water and ice, we do not need to suppose that something called "aquosity" or "the crystalline principle" enters from without into the combined oxygen and hydrogen, and builds the molecules into star-shaped compound crystals. But if all experimental efforts had failed to get water to crystallize, except when in contact with pre-existing ice-crystals, or to get hydrogen and oxygen to combine and form water, except in

the presence of pre-existing water; these would be parallel cases to the actual case of living beings; and the first origin of water, or of ice, would be a question of exactly the same kind as is the actual question of the origin of life. The facts that hydrogen and oxygen always combine and form water when their temperature is sufficiently raised, and that water always crystallizes into ice when sufficiently cold and still, make it certain that the properties of water and ice are resultants from the properties of oxygen and hydrogen, though we do not know how they are so; but we should no doubt see the manner and cause of the fact, if we understood atomic physics as we understand the construction of a watch: and I have nothing to say against the supposition that if we understood life as we understand mechanics, we should be able to deduce the properties of living beings from those of carbonic acid, water, and ammonia. But it is at least credible, and seems to be most probable, that the same knowledge would show the formation of the lowliest living being, by the spontaneous powers of the chemical substances of its structure, to be no more possible than the formation of a watch by the spontaneous powers of brass and steel. The properties of living beings, the laws of habit, of organization, of intelligence, and of consciousness, appear absolutely unlike anything to be found in mere matter and force. It is indeed a mystery which there is no hope of ever completely solving, that laws and forces so unlike as those of matter and of life should co-exist and work together. This is true even of the merely organic life: but how much deeper is the mystery when life is known to include feeling, thought, and will!.

Probable conclusion that Life, like the Universe, was created at a definite time.—The probability that life has originated by a distinct creative act, and at a definite period of past time, is greatly strengthened by the demonstrated truth that the present order of the material universe has not been from eternity, but must have begun at a time not infinitely remote. It was an idea of the ancient Stoics, and survived into modern times, that

all changes in the universe move as it were in closed curves, in which everything comes round again to what it was at first: so that the universe may have existed from an eternal past, and may continue to exist without substantial change through an eternal future. But the modern science of energy has disproved this, by showing that actions are constantly going on which are incapable of being reversed. Heat is constantly diffusing itself, and when it is diffused there is no power in nature which can concentrate it back again. This causes a destruction of motive power, because heat is incapable of being transformed into motive power when it is equally diffused: to use a familiar illustration, a steam-engine could do no work if the condenser were as hot as the boiler. Thus, by reason of the irreversible process of the diffusion of heat, the stock of motive power in the universe is constantly diminishing, and all things are tending to immobility. If we had the means of ascertaining how much motive power in the universe has been destroyed, and at what rate the destruction is going on:—and though we cannot hope to ascertain these data for the entire universe, we know them in some degree of approximation for the solar system:—if we knew these data, I say, it would probably be within the power of mathematical science to ascertain approximately the date at which the destruction of motive power began; and this would be identical with the date of the absolute beginning of the existing order of nature.

Clerk Maxwell on the Origin of the Universe.—To quote Professor Clerk Maxwell:[1]—"We thus arrive at the conception of a state of things which cannot be conceived as the physical result of a previous state of things, and we find that this condition actually existed not in the utmost depths of a past eternity, but separated from the present time by a finite interval. This idea of a beginning is one which the physical researches of recent times have brought home to us more than any

[1] From his address to the Mathematical and Physical Section of the British Association, 1870.

observer of the course of scientific thought in former times would have had reason to expect."

Clerk Maxwell on the Origin of Matter.—On the kindred subject of the origin of matter, let me quote Professor Clerk Maxwell again :[1]—"In the heavens we discover by their light, and by their light alone, stars so distant from each other that no material thing can ever have passed from one to another; and yet this light, which is to us the sole evidence of the existence of these distant worlds, tells us also that each of them is built up of molecules of the same kind as those which we find on earth. A molecule of hydrogen, for example, whether in Sirius or Arcturus, executes its vibrations in precisely the same time. Each molecule, therefore, throughout the universe bears impressed on it the stamp of a metric system as distinctly as does the metre of the archives at Paris. No theory of evolution can be formed to account for the similarity of molecules, for evolution necessarily implies continuous change, and the molecule is incapable of growth or decay, of generation or destruction. None of the processes of nature, since the time when nature began, have produced the slightest difference in the properties of any molecule. We are therefore unable to ascribe either the existence of the molecules or any of their properties to the operation of any of the causes which we call natural. On the other hand, the exact equality of each molecule to all others of the same kind gives it, as Sir John Herschel has well said, the essential character of a manufactured article, and precludes the idea of its being eternal and self-existent. Thus we have been led, along a strictly scientific path, very near to the point at which science must stop. In tracing back the history of matter, Science is arrested when she assures herself on the one hand that the molecule has been made, and on the other that it has not been made by any of the processes which we call natural. Science is incompetent to reason on the creation of matter itself out of nothing. We have reached the utmost limit of our thinking

[1] From his address on "Molecules," to the British Association in 1873.

faculties when we have admitted that because matter cannot be eternal and self-existent, it must have been created."

It is a strange irony whereby the atomic theory, which commended itself to Epicurus as the best basis for an atheistic philosophy of the universe, proves to be that which of all physical theories leads most directly and inevitably to the acknowledgment of a Divine Power and Intelligence.[1]

Possibility of Successive Creative Acts.—There is among many a strong prejudice against "the conception of successive creative acts;" but it seems to be unfounded. Granting, what cannot be denied, the soundness of the proof that the order of nature cannot have gone on from a past eternity, it follows that there must have been an absolute beginning; and why may not new laws and powers have been introduced into the universe at one time, or at sundry times and in diverse manners, since the beginning? Is it because an act of creation is inconceivable—that is to say, inconceivable by *our* intellects? No doubt it is so: but the notion of any finite thing existing without having been created is more than inconceivable—it is absurd. It is quite true that the ordinary administration of the world is not by a succession of creative acts, but by evolution under natural law. But we believe this for no reason except that we find it to be so: and the most widely established laws may be found to admit of limitations and exceptions. Modern materialists admit—some of them strongly insist—that the best established laws of nature are, or may be, only approximations to the truth: and that the law of gravitation itself may be subject to limitations. They derive all knowledge from experience: and as regards the world of nature they are certainly right. But all conclusions from experience are subject to be modified by further experience: and therefore,

[1] This was seen by Cudworth. See his *Intellectual System of the Universe*, first chapter, beginning with the 27th section. He appears, however, to think that the properties of matter, as such, are purely passive: a theory which is contradicted by all that has been made known by modern research, and inconsistent. apparently, with one of the commonest of all facts, namely that of weight.

on their own postulates, they have really no ground for rejecting as inadmissible the conception of successive creative acts.

The Origin of Species is a Distinct Question from that of Life.—The question of the origin of distinct species is quite distinct from the origin of life, just as the question of the origin of the existing universe, which modern science refers to the condensation of a nebula, is quite distinct from the question of the origin of matter. I believe, to its fullest extent, in the theory of the derivation of all living species, vegetable and animal, by descent with modification from one or a few originally vitalized germs; though I differ from Darwin and Spencer as to the agency whereby the modifications have been effected.

Seed-bearing Meteors.—Sir William Thomson's suggestion may perhaps be true, that the first germ of all the life on our planet was brought by a meteoric stone from the wreck of some older world; though it appears scarcely credible that its vitality could survive the intense heat which is produced by the fall of a meteoric stone through the air; but were this proved, it would not bring us one step nearer to the absolute beginning of life.

CHAPTER IV.

ORGANIZATION.

Life is the Cause, not the Effect, of Organization.—We have seen that structure and organization are not the cause of life but only one of its most general effects; and the proof of this is, that the entire bodies of some of the lowest organisms, and the "germinal matter" of the highest, possess life without organization.

Illustration from Inorganic Nature.—This may be illustrated by what we see in inorganic nature, where form and structure are often the result of the action of certain powers, but never the cause of those powers. Forces which are simply attractive, and not polar, produce spherical forms by their action: thus, gravitation produces the form of planets and capillarity that of raindrops; but the spherical forms do not produce attractive or any other forces. Crystalline form and structure, again, are produced by a peculiar and little understood kind of molecular polarities; but the form and structure which are produced by those forces have no tendency to produce them in turn.

Formative Power of Germinal Matter.—It needs no proof that any uncrystallized but crystallizable material, such as a salt in solution, has a tendency to assume its characteristic crystalline form, and does assume it when circumstances favour. The same is true of the unformed but formative material, or "germinal matter" of organisms: the germinal matter of every species

constantly tends to assume the form and structure of the species to which it belongs. Hence the power of a germ, when placed under favouring circumstances, to transform itself into the perfect form of the species. Hence also the power, among many plants and among the lowest animals, of a cut-off part to transform itself into a perfect individual, and, what is only a lower degree of the same, the power of repairing injuries.

All the Germinal Matter of the same Organism is probably Alike.—It appears most likely that all the germinal matter found in the same organism is exactly alike when first produced; so that any germinal matter is able to minister to the growth of any tissue or organ. This view is supported by the fact that the smallest portion from any part of a *hydra* or other such low organism will reproduce the entire form of the species.

All Germs are perfectly Simple and visibly Alike.—The germs of organisms are not miniatures of the mature form, nor are the mature forms produced by any process that can be described as unfolding:[1] on the contrary, the germs are without structure and without definite form, and present no character whatever, whether chemical or microscopic, whereby the germ of one organism can be distinguished from that of another, however unlike the mature forms may be. From a purely scientific point of view, this fact is perhaps the most important of all the discoveries of modern physiology.

Their Different Properties cannot be accounted for by Differences of Molecular Structure.—It may be maintained that the capacity of apparently similar germs for developing into very dissimilar organisms, is really due to differences of structure which elude the microscope by reason either of the minuteness of the structure or of the uniform transparency of the germinal matter.

[1] The words *evolution*, *development*, and *entwickelung*, though they are not now misleading, imply an erroneous conception of fact. The process indicated by these words does not consist in unfolding or in simplification, but quite the reverse—it is constantly increasing complication and variety. To speak technically, evolution is differentiation.

Very probably there is far more structure than the microscope will ever reveal, in the simplest organism and in the smallest part of every organism. It is quite credible that, on a scale intermediate between the structures revealed by the microscope and the chemical atoms, there may be a whole world of structure which must remain for ever inaccessible by any of our methods of investigation. But it seems impossible that the properties of germinal matter can be due to structure at all. No hypothesis of the kind will account for the facts of hereditary transmission. The peculiar habits of the higher animals and of human beings, so far as they are characters of the individual only, may be ascribed with some plausibility to peculiarities of the nervous mechanism of the brain. This may be true, for instance, of the habit which the sheep-dog has acquired of running round, instead of at, a flock of sheep. But the young sheep-dog is born with the same tendency: and no mechanical theory can account for this:—a mechanical theory can no more account for the hereditary transmission of tendencies, than a machine can propagate its kind. We therefore conclude that there is something in all life which transcends mechanism and structure.

Organization defined as Adaptation of Structure to Function.—Organization is to be defined as the adaptation of structure to function. The adaptation of structure to function, and of one structure and one function of an organism to another, is characteristic of the organic creation, and totally unlike anything in the inorganic world.

Three Chief Relations in Physical Science: Cause, Resemblance, Purpose.—There are three principles of relation that run like guiding threads through physical science. These are—

1. The relation of cause and effect;
2. The relation of resemblance and difference; and
3. The relation of means and purpose.

For brevity let us call these cause, resemblance, and purpose.

This is not offered as an enumeration of all possible relations.

I well know it is nothing of the kind. But, as a matter of fact, these are the most important relations that we meet with in the physical sciences.

Cause Predominates in the Dynamical Sciences.—The relation of cause is the principal one that we have to do with in the dynamical sciences, including those of sound, light, heat, electricity, and magnetism; and the same is true of the more elementary branches of chemistry. The general problem of this entire group of sciences is to infer causes from effects and effects from causes.

Chemistry, how far Classificatory.—But in the higher or more complex chemistry, especially in the chemistry of organic compounds, the known and possible combinations are so many, and the variety of interactions so great, that it is at present impossible to do in chemistry what we are doing in the dynamical sciences—namely, to refer the multitude of facts to a few causal principles. But the same multiplicity of facts which places knowledge of their causes at present beyond our reach, supplies us with a new principle of relation, namely that of resemblance. Compounds are formed in series, and in series of series; and this relation is most decided in the higher or more complex chemistry. Chemistry in its higher branches has thus become a classificatory science.

Crystallography is a Classificatory Science.—Crystallography also is a science in which causes are as yet almost totally unknown. We can only describe and classify crystals by their chemical constitution, their form and structure, and their optical properties. Crystalline species exist in groups, and in groups of groups[1]—to use technical language, in genera and classes. Crystallography is thus a classificatory science.

[1] The difference between a series and a group is that the names of a group may be enumerated in any order, those of a series properly in only one order. The oxides of a metal, for instance, which are formed by the successive addition of equivalents of oxygen, constitute a series.

Morphology, the Classificatory Part of Biology.—A very large part of biology, or the science of life, consists, like crystallography, of the description and classification of the forms of various species. Organic species, like crystalline species, exist in groups, and in groups of groups. The description of the forms, both in crystallography and in biology, constitutes morphology; and the ascertainment of the fundamental relations, which are not always the obvious relations, between the forms, is the problem of classification. Biology is thus a classificatory science.

Physiology, the Functional Part of Biology.—But morphology and classification constitute only half the science of biology, and its least characteristic half. Crystals, like organisms, have their morphology and their classification, but they have no adaptation of structure to function, because they have no functions; function, in the organic sense, is impossible in bodies which exist only on condition of perfect molecular immobility. In organisms, on the contrary, structure and function are mutually adapted, and structure depends on function. Consequently, the second and most characteristic part of biology consists in physiology, which is defined as the science of organic functions, and of the relations of structures to their functions.

Distinction of Purpose from all other Relations.—I shall probably be told that in saying that the relation of structure to function is the same with the relation of means to purpose, I am assuming as true an unverified hypothesis.

I reply, that the relation of special structure to special function, as for instance the relation of the structure of the eye to the function of sight, has no analogy in the inorganic creation, though it has analogies in machinery and other apparatus of human invention. The analogy of the eye to the camera obscura is a case in point; in fact, the eye is a camera. We cannot avoid speaking of the function of an organ and of its purpose, as if the words were synonymous: and this is not found to be

misleading: on the contrary, it is a rule in biological research, though subject to some remarkable exceptions, that every organ and every structural arrangement must have its own special purpose.

No doubt the law of causation is coextensive with the universe, but it does not follow that every relation in the universe must be a case of causation. This will be made clear by considering the analogy of human art which has been already mentioned. Every human work has been constructed by definite means and for a definite purpose; but the question by what means it has been constructed, is distinct from the question for what purpose it has been constructed; and a statement that answers the one may be no answer to the other. The purpose of the Menai tubular bridge is to shorten the distance between the capitals of England and Ireland, but this statement gives no information as to the means whereby it was put together and raised into its place.

It is impossible simply to deny the existence of the most wonderful special adaptations in the organic creation. But it has been argued with great knowledge and great ability by Darwin, in his *Origin of Species,* and by Spencer, in his *Principles of Biology,* that the laws of cause and effect are adequate to account for all these—that the adaptation of the eye to light, for instance, has been produced by the direct and indirect action of light on countless generations of living beings.

Purpose is most Traceable where Cause is least so.—From this theory I altogether dissent, and in future chapters I shall endeavour to meet it with detailed arguments. I will here only remark, as a presumption against it, that purpose is most clearly discernible where cause is least so. As we ascend in the scale of nature to higher vital functions and higher organic forms, we find that the relation of cause and effect becomes less traceable by our faculties; while the relation of means and purpose becomes at once more traceable and more definite. Nowhere is the relation of means and purpose more clearly

traceable and more perfectly definite than in the organs of special sense in the higher animals, especially the eye and the ear; and nowhere is it more difficult, not to say utterly impossible, to assign any merely physical cause for the facts, as when we inquire by what agency those wonderful organs have been formed. And as we ascend in nature, not only do the separate functions become more traceable, but their relations to each other and to the entire organism become more definite. The trunk, the leaves, and the flowers of a tree, for instance, have each their function, but it would be unmeaning to ask whether the tree exists for the leaves, or the leaves for the tree. But in all the higher animals the parts manifestly exist for the whole, not the whole for the parts.

Inaccuracy of the Expression Final Cause.—The truth that the relation of purpose is distinct and not resolvable into any other, has probably been obscured by the use of the expression *final cause* in the sense of creative purpose. This expression, as applied to organic adaptations, is doubly inaccurate. They are not causes, but are another class of relations; and they are not final, but are ends which are also means.

The Purposes in Organization are only Relative.—In other words, the purposes revealed in organization are only relative purposes. As Kant has remarked, in an organism all the parts are mutually means and ends. But if we ask what absolute end is attained or aimed at by this wondrous play of means and relative ends, science has no answer to suggest. And it is equally true that science, though conversant with the relations between effects and their relative causes, has nothing to tell of any absolute originating first cause, except only that it must exist.[1]

[1] See p. 42.

CHAPTER V.

DEVELOPMENT.[1]

We have seen that the germs of all organisms are without organization or structure. Organization consists in the mutual relations of parts, and development consists in the formation of structures by differentiation out of the homogeneous germinal matter or protoplasm.

Development and Repair.—Normally, development is from the germ to the perfect form. But the process is essentially the same when a lost part is reproduced, or an injury repaired. All organisms appear to possess something of this power ; the newt will reproduce a lost leg or even a lost eye ; and there have been some remarkable instances of the same power in man, though in most cases it does not go farther than the healing of wounds.[2] Normal development consists in the gradual transformation of the formless germinal matter into the formed material of the tissues, and abnormal development, in the process of repair, are essentially the same ;—both consisting in the transformation

[1] It will be observed that I have adopted Dr. Beale's views on the subject of "germinal matter," as set forth in his edition of Todd and Bowman's *Physiology*. It is however to be regretted that Dr. Beale has stated a true and valuable theory in language that can scarcely fail to excite a prejudice against it. He speaks of life as being confined to the germinal matter—by life, evidently meaning the formative principle. In the sense in which he uses the word, I have no doubt that he is right, but it is an unwarrantable liberty with language to use the word life in a sense that would exclude the contractility of muscle, and the sensibility of nerve, from the denomination of vital functions.

[2] Carpenter's *Human Physiology*, p. 464.

of germinal matter into the formed material of the part under repair. The germinal matter, which is found in small quantities throughout every living part of the organism, increases in quantity during the reparative process.

Germinal Matter and Formed Material.—The transformation of germinal matter into formed material, or tissue, goes on not only during growth and repair, but throughout life, in the renewal of the tissues to supply their waste. The assimilated food must be transformed into germinal matter before it becomes tissue. The power of growth and development appears to reside exclusively in the germinal matter. There does not appear to be any hard and fast distinction between germinal matter and formed material; but the more completely the formed material has assumed a character unlike that of germinal matter, the more completely it has lost the power of transformation and development.

Instance in Gromia.—It is only in the lowest organisms that this distinction can be made perfectly evident. The *gromia*, for instance, consists of nothing but a minute mass of gelatinous matter, enclosed in a membranous sac open at one end.[1] If the gelatinous matter is emptied out of the sac, it will form a new sac for itself, but the sac will not form new germinal matter, nor will it manifest any vital properties.

Germinal Matter in the Higher Organisms.—In this simplest possible case, we see that the germinal matter will produce formed material, but not the converse. In the case of the higher organisms the same experimental proof is of course impossible, but all evidence and all analogy lead to the conclusion that the same relations hold throughout the entire organic creation. The sarcode, or gelatinous substance which constitutes the entire bodies of such organisms as *gromia*, *amœba*, or *hydra*, appears to be similar in its properties to the protoplasm or

[1] Carpenter on the *Foraminifera*, published by the Ray Society, p. 63.

germinal matter which is found in small quantities throughout the bodies of the higher organisms. The white blood-corpuscles of the higher animals consist of germinal matter; like the sarcode of the lowest animals, they are without structure, and when, during inflammation, they make their way through the walls of the blood-vessels, they perform spontaneous movements like those of an *amœba*.[1]

The sarcode of the lowest animals manifests its germinal powers by the smallest portion continuing, when separated, to live, and giving origin to a new animal. The germinal matter of the higher animals does not possess this power, but we cannot infer that its functions are fundamentally different. The difference consists only in this, that any fragment of such an animal as a *hydra* can live wherever it has water and food, but the germinal matter of one of the higher animals can live only within an organism suited to it.

Propagation among the Lower and the Higher Organisms.—The same difference to some extent explains the difference between the modes of propagation among the lower and the higher organisms. The lowest organisms, such as the rhizopods among animals and the diatomaceæ among vegetables, often propagate by spontaneous division: the individual separates into two parts, each of which contains a portion of germinal matter, and continues to live and to grow. The *hydra* is more highly organized than these, and is not known to divide spontaneously, but separated parts will live.

Cellular Structure and Muscular Fibre.—In the ordinary process of development, the separation of the formed material takes place on the outside of the mass of germinal matter. This process gives origin to cells, whereof the inside consists of the half-liquid germinal matter, and the outside of the harder formed material. The *gromia*, mentioned above, is an animal

[1] Report on Cohnheim's Researches on Inflammation and Suppuration, by J. M. Purser, M.B. *Proceedings of the Royal Irish Academy*, vol. x., p. 499.

consisting of a single cell; and among vegetables whole tribes consist of the same, especially the diatomaceæ and desmideæ, which are classed as very simple forms of Algæ. A great part of the tissues of the higher animals and vegetables consists of such cells, variously modified. So common, indeed, is this formation, that the cell was formerly regarded as the primary element of all organized tissue; but more recent research has shown that this is not the case. A kind of rudimentary muscular tissue has been obsérved to originate in the larvæ of the Echinoderms (star-fish and sea-unchins), not by any transformation of cellular into fibrous tissue, but by fibrillation of the homogeneous transparent sarcode substance composing the body of the larva.[1] And the researches of Dr. Wilson Fox on the development of striated muscular fibre[2] appear to show, that though the fibres are developed by the elongation of cells, yet, in addition to this, the protoplasm or germinal matter within the elongated cells becomes itself fibrillated; while the membranous wall of the primary cell becomes the sarcolemma, or membranous sheath of the muscle.

[1] Professor Wyville Thomson on the "Embryology of the Echinodermata," *Natural History Review*, October, 1864. The kind of larva in question is called by him the pseudembryo, to mark the total unlikeness between the development of Echinoderms and true metamorphosis like that of insects.

[2] *Philosophical Transactions*, 1866. It ought to be mentioned that Dr. Wilson Fox has not been able to see the membranous wall of the primary cell, but infers its existence from the analogy of other structures.

CHAPTER VI.

THE DIRECTION OF DEVELOPMENT.

High Organization consists in Distinctness of Dissimilar Parts.—All development, as we have seen, is from the simple to the complex—the highest organization is the greatest complexity.

High organization does not consist in mere multitude of parts. The multitude of leaves on a tree is no mark of high organization. What constitutes high organization is not multitude of similar parts, but distinctness of dissimilar parts. In man, or any other of the highest organisms, no two parts are exactly alike except those which correspond with each other on the opposite sides of the body.

Physiological Division of Labour.—We have seen that all living beings are constantly assimilating matter and parting with it again by waste, and that they are constantly storing energy and parting with it again, transforming it generally into either motion or heat. All organisms, also, propagate their kind. All organisms consequently have a considerable complication of functions, even those which have no complication of structure: and development consists in fitting separate structures for the discharge of separate functions: one set of organs for the nutritive or assimilative function, another for the excretory, a third for the motor, a fourth for the reproductive, and so on. To use what is not only a metaphor but a real analogy, organization consists in framing the various parts of the organism for the physiological division of labour.

Interchange of Functions between Organs.—In the lowest organisms there is no physiological division of labour, and in the highest it is not complete: some of the organs can in a great degree discharge the functions of others. In man, for instance, the skin and the kidneys are to a great extent able to do each other's work in separating water and soluble substances from the blood; and in some cases of disease one excretory organ assumes the whole work of another. This power is no doubt in some way due to the common origin of all organs and all tissues in one homogeneous and structureless germ; but the highest organisms have the least of this power, because in the highest organization the various parts minister to each other the most perfectly, and are therefore the least able to do without each other.

Physiological Centralization.—We call the separation of functions the physiological division of labour, and the mutual dependence of parts and the combination of their action may be called physiological centralization. The two are necessary to each other. In the organism, as in human society, division of labour is necessary to combination, and combination for a common object, with some degree of centralized control, is necessary to division of labour.[1] It appears to be generally impossible that high perfection for any special purpose should be compatible with adaptability to a variety of purposes. This is alike true of tools, of members of the living organism, and of men. It is impossible that a saw and a plane should do each other's work. It is inconceivable that colours should be perceived by the ear, or sounds by the eye. And it is a familiar remark that a man who has attained to perfection in some special mechanical—and, perhaps we may add, in some special

[1] Any argument in favour of political centralization which may be based on this, is not only worth little by reason of the remoteness of the analogy (though it is a real and not a merely fanciful analogy), but is vitiated by the all-important difference that in the living organism the parts exist for the whole, but in society the whole exists for the parts—society exists for its members.

intellectual—employment, is thereby in a great degree incapacitated for any employment that needs nothing but the power of doing a variety of work moderately well.

Morphological Definiteness.—From physiological division of labour follows definiteness of the number, position, and form of parts. When every part has its perfectly definite function, it follows that the number, form, and position of parts must be definite. In the lower organisms the number of the parts, especially, is often very indefinite, but as we ascend in the scale of organization it becomes definite. In worms and millipedes, for instance, the number of segments is variable between different individuals of the same species, but it is constant among crabs, spiders, and insects, which are more highly organized on the same fundamental plan.

Summary.—What precedes may be summed up by saying that the higher the organization the more complete are the physiological division of labour, the physiological centralization, and the morphological definiteness.

Separation of Hard External from Soft Internal Parts.—The first and most general differentiation of organs is that produced by the gelatinous matter which constitutes the entire substance of some of the lowest organisms becoming more consolidated on the outside than on the inside. Thus are produced the single cells that constitute the diatomaceæ among plants and the *gromia* among animals. The higher organisms consist, in great part if not altogether, of variously modified cells; and in them the external cells are generally condensed into a denser and sometimes hard tissue, the function of which is to protect the interior organs: while the tissues of the interior, where the vital processes are going on, continue soft. Thus in vegetables and animals, and in the lowest and the highest organisms alike, the exterior parts are consolidated in order to protect the interior parts and to hold them together.

Separation of the Reproductive from the Nutritive Organs.—The next differentiation we meet in the ascending scale of nature is that into the nutritive and the reproductive systems : that is to say, into those organs which minister to the life of the organism itself, and those which provide for the existence of future organisms of the same kind. It is important to observe that the distinction between growth and reproduction is not fundamental. When buds are formed and remain attached to the parent organism, as in the case of a tree, the process is called growth : when they detach themselves and continue to live, as in the case of a *hydra*, the process is called reproduction :—it is obvious that there is no fundamental difference between these.—Sexual reproduction is now regarded as merely a modification of the budding process.

The usual mode of propagation of the *hydra* is by means of buds, which may be formed on any part of its external surface, and develop into perfect *hydræ*, when they detach themselves and creep away. The so-called coral-insects, which belong to a class allied to the *hydra*, are propagated in the same way, except that the newly-formed animals do not become detached; and the growth of a tree, by throwing out buds, is similar to this : each bud, in many species, is capable of becoming a new plant; and indeed a tree, no less than a coral reef, may be regarded as an assemblage of individuals rather than a single individual. In these modes of propagation the reproductive power belongs to every part of the organism alike; but in the higher animals the reproductive power is confined to special organs, the function whereof is to prepare and throw off masses of germinal matter in a suitable form: and, further, to provide the germ with protection and nourishment, either in the egg or in the womb, until it has attained to some degree of maturity.

Vascular Structure.—Probably the differentiation that comes next in generality, is that of vascular structure, which, in its simplest form, consists of rows of cells which have been joined to each other by the removal of part of their walls, so as to

form tubes for the passage of nutritive fluids from one part to another. Vessels are not needed, and consequently do not exist, in those organisms where all the parts are alike in structure, and equally well-situated for obtaining nourishment. Thus among sea-weeds every part is separately able to derive its nourishment from the water, and there is no vascular system: but some rudiment of vascular structure is found in all air-breathing plants, except the simpler lichens and fungi. In these latter, any movement of fluid that may be necessary is by permeation, for all living tissues are permeable by water.

The Nervo-muscular System is the peculiar Animal Character.—The reproductive organs, and the vascular or circulatory system, though separated from the general nutritive system, continue nevertheless to form part of the organs of nutritive or vegetative life. The next differentiation that we have to mention is probably the profoundest of all. We have seen that the differentiation of life consists in the power of effecting a peculiar set of transformations of matter and energy. The peculiar characteristic of the animal kingdom is the possession of a nervo-muscular system, which is a distinct apparatus for the transformation of energy, and constitutes the organs of animal life.

Classificatory Distinctions are seldom Absolute.— It must however be observed that the distinctions of organic classification are seldom if ever absolute. Some vegetables have what may almost be called a muscular system,[1] and the lowest animals have neither muscular nor any other distinct organs.

Analogy between the Nervous and the Vascular Systems.—A muscular system is found in some animals, as among the Hydrozoa, which are not known to have any rudiment of nerves; but the converse does not occur: there are never any nerves except where there are distinct muscles. Nerves have

[1] See note at end of chapter.

to the muscular system somewhat the same relation which sap or blood-vessels have to the nutritive system. The analogy is not close, but it is real. The function of the vascular system is to increase the efficiency of the nutritive system by conveying nutritive material from one part of the body to another more rapidly than it could be conveyed by mere permeation; and the primary function of the nerves is to increase the rapidity and precision of combined action among the muscles, and thereby to increase the efficiency of the muscular system, by transmitting stimuli from one part to another more rapidly than they could be transmitted through the muscular tissue itself. It was said long ago by John Hunter that the function of the nerves was *internuncial;* and Helmholtz has shown that an influence, in some degree resembling electricity, though not identical with it, runs along a stimulated nerve at a velocity which he has succeeded in measuring. On stimulating by electricity a piece of muscle taken from a newly-killed frog, the muscle contracts. On applying the same stimulus to the loose end of the motor nerve in connection with the muscle, the muscle again contracts; but between the application of the stimulus at the one end of the nerve and the contraction of the muscle at the other end, a time elapses which has been measured by the delicate electric apparatus employed by Helmholtz, from which he estimates the rapidity of the transmission of impulses along the motor nerves of the frog at from 81 to 126 feet per second; and he estimates the rapidity for human nerve at somewhat more than 200 feet per second.[1]

It is scarcely possible to doubt that what is transmitted along the nervous fibres is some form of vital energy. If so, we find this remarkable parallelism—that the function of the nutritive system is to transform matter, and that of the muscular system to transform energy; the function of the vessels is to convey matter, and that of the nerves to transmit energy.

[1] Carpenter's *Human Physiology*, p. 614.

What Nerves Transmit is Stimuli.—The parallelism, though real, is however less exact than might be inferred from this statement; for what the nerve transmits to the muscle is only a stimulus to contract: the energy which is transformed from the vital into the motor form in the contraction of the muscle is not brought to it by the nerve, but is transformed in and by the muscle itself. This is shown by the remarkable discovery mentioned in a previous chapter, that vital energy accumulates in muscles which are cut off from nervous stimuli by the cutting of the nerve-trunks;[1] and it is further shown by the familiar fact that those muscles become most fatigued which are most overworked—which obviously would not be the case if fresh supplies of energy were brought to the muscles as fast as they were wanted.

Electric Action on Nerve.—In Helmholtz's experiment mentioned above, also, and in the well-known experiment of making the cut-off legs of a frog kick by means of an electric stimulus, the electricity is nothing more than a stimulus, or excitor to action; it does not supply the motive power. The motive power in this case, as in the living frog, is obtained by the transformation of the vital energy stored in the muscles. This is shown by the fact that the cut-off legs *become fatigued* with repeated stimulation, and kick less forcibly, but recover their power when laid by for some time, which obviously would not be the case if the motive power were supplied by the transformation of the electricity.[2]

Parallelism between the Nervous and the Vascular Systems.—The parallelism between the nervous and the circulatory systems is shown in various ways. The nerves and the blood-vessels resemble each other in ramifying and inosculating throughout the entire body; and also in this, that the action of both is in a great degree, though not absolutely, controlled by great central organs—the circulatory system by the heart, and the nervous

[1] See p. 29. [2] See p. 32.

system by the spinal cord and the brain. Circulatory centralization and nervous centralization are seen to increase together as the animal scale ascends. It is a most interesting instance of this, that the *amphioxus*, a fish which is the lowest of all vertebrates, is without a brain, though it has a spinal cord, and is also without a distinct heart, instead of which it has several pulsating enlargements of the blood-vessels. These two characters make it quite unique among vertebrates.

The same parallelism is further shown in this, that those parts of the body which are the most abundantly supplied with blood-vessels are also the most abundantly supplied with nerves; and the nails and hair, which are without blood-vessels, are also without nerves. The activity of the two is heightened or lowered together. The vessels of inflamed parts are unusually full of blood, and the action of their nerves is heightened: this last is shown by their increased sensibility. And, what is a parallel fact to this, during sleep, which essentially consists in a lowered action of the brain, the blood-vessels of the brain are comparatively empty; and so are those of the retina. It is possible to lower the nervous activity so as to destroy the sensibility of any part, by tying the arteries so as to deprive it of its supply of fresh blood.

Action of the Nervous on the Vascular System.—It belongs to this class of facts that the heart, which is the central circulatory organ, is more easily acted on by nervous influence than any other organ of the vegetative life. The susceptibility of the heart to those nervous influences which arise from the emotions have caused it in popular language to be regarded as their seat. Reciprocally, the brain, which is the central nervous organ, is more sensitive than any other organ of the animal life to influences arising from variations in the flow of the blood. There is thus a remarkable and very intimate set of interactions between the heart and the brain. In sleep, as we have seen, the blood-vessels of the brain are comparatively empty; and uncon-

sciousness—that is to say syncope, or what is commonly called a fainting fit—is the result of a failure in the supply of fresh blood to the brain. Thus, syncope, which may be produced by loss of blood through a wound, may be produced also by a violent emotion, whereof the brain is of course the seat, acting through the nerves on the heart so as to check its pulsations; and thus reacting on the brain by depriving it of its supply of fresh blood.[1]

The Action is not Reciprocal.—But though the activity of the nervous system depends on the supply of blood, the converse is not true; the activity of the circulatory system does not in any similar way depend on nervous influence. As we have seen, the nerves of a part are paralysed by tying the artery that supplies it; but the circulation of a part is not stopped by cutting the nerve-trunk that supplies it.

Contrast between the relations of Blood and Nerve to Muscle.—Moreover, it has been shown by experiments on cold-blooded animals that there is a remarkable contrast between the relations of blood and nerve to muscle. It is a familiar fact that the stimulation of a motor nerve tends to cause the muscle in connection with it to contract. It has been also ascertained that the supply of fresh arterial blood tends to cause muscular fibre to retain the relaxed or elongated state, and when the supply of blood is cut off the muscles contract spontaneously. In other words, blood tends to keep the muscles elongated, and nervous influence makes them contract.[2] To state these facts in the language of the dynamic theory: The blood undergoes

[1] "Chez l'homme, le cœur est le plus sensible des organes de la vie vegetative: il reçoit le premier de tous l'influences de la circulation du sang. De la resulte que ces deux organes culminans de la machine vivante sont dans des rapports incessans d' action et de reaction. Le cœur et le cerveau se trouvent dès lors dans une solidarité d' actions réciproques des plus intimes, qui se multiplient et se ressèrrent d' antant plus que l' organisme devient plus développé et plus delicat."—CLAUDE BERNARD, *Revue des Deux Mondes*, April 1865, p. 250.

[2] See Dr. Norris's "Report on Muscular Irritability" (British Association Reports, Nottingham, 1866).

oxidation in the lungs; in the process of oxidation energy is liberated, part of which is carried by the blood to the muscles, and supplies them with their charge of vital energy. So long as they remain elongated, they retain this charge, but when a nervous stimulus makes them contract, the vital energy is transformed into motor energy.

These facts appear to show that the blood supplies the various parts of the body with energy as well as with matter. The nerves, of course, transmit energy only.

Summary.—What has been said on the direction of development may be thus summed up:—

Every organism transforms both matter and energy, and it is probable that every living part of an organism always continues to transform them both. The characteristic of animal development is that one set of organs—the nutritive—is specially appropriated for the transformation of matter; and another—the nervo-muscular—for the transformation of energy. The nutritive or vegetative system of organs is for the most part internal, and the characteristically animal organs—those of the limbs and the mouth, with their muscles—are external to the nutritive. In both vegetables and animals a circulatory system is developed, the function of which is to minister to the nutritive life by the circulation of nutritive fluid; and in animals a nervous system is developed, the primary function of which is to ensure the harmonious and efficient action of the muscular system by the transmission of stimuli from one part to another.

Nerve-Fibres and Ganglia.—Any account of the relation of nerve to muscle would be imperfect were it not mentioned that nerve-fibres never exist without ganglia, and that it appears to be impossible to communicate a stimulus from a sensory to a motor nerve-fibre except through a ganglion. The action of ganglionic tissue is even more mysterious than that of nerve-fibre. It has been often said that the ganglia are the generators of nervous energy, and the nerve-fibres its conductors; but Mr.

Lewes has shown that this account of the matter is at least insufficient. A nerve-fibre is capable of acting when it is not in communication with a ganglion, as is proved by the experiment of making the cut-off leg of a frog kick by exciting its nerve with electricity.

NOTE.

THE CONTRACTILITY OF THE FILAMENTS OF THE THISTLE.

In the *Edinburgh New Philosophical Journal* of October, 1863, p. 190, there is an interesting account of the observations of Cohn, of Breslau, on this subject.

When the anthers are ripe, the filaments twist about in a remarkable way, for the purpose of forcing out the pollen. This is best seen if the stamens are cut away from the corolla, so as to show the tube formed by the adherent anthers, with the filaments hanging loose from it: "the latter, on every touch, exhibit the liveliest irritability, throw themselves backwards, straighten themselves again, bend to the opposite side, and wind round one another. One might fancy that it was a *hydra*, rather than a vegetable organism. This contraction may be induced by electrical stimulus."

"When the filament is elongated, the inner cells, seen in longitudinal section or otherwise, appear *longitudinally striated*, as if they were provided with longitudinal fibres." On the contrary, "by death the filaments are contracted to their minimum length"; and this cannot be due to drying, because they contract even when killed by soaking in water, glycerine, or alcohol. "The filament consists of a central bundle of annular and closely wound spiral vessels, surrounded by longitudinal rows of long cylindrical cells, with straight partition walls"; the cells when dead are "closely cross-striped—to appearance, as if the filament consisted of a number of spiral vessels. In those places where especially shorter cells occur, there is the *closest transverse striation almost like that of striped muscular fibre.* This striation is caused by a very regular and close transverse corrugation of the cells in the contraction of the filament; hence the side walls of the cells appear finely and closely wrinkled, so that ten to twenty cross-folds occur in every 300th of a millimetre." "The filaments in shortening," as might be expected, "become thicker." It will be seen how very closely this contraction resembles that of muscle; and Cohn believes that here, as in the case of muscle, "the cells of the elongated filament are in a state of active expansion," or, as I express it, that they contain a charge of energy:[1] and that their contraction depends on their elasticity, which comes into play when the expanding force is discharged, and is not destroyed by the death of the fibre.

[1] See p. 30.

CHAPTER VII.

ORGANIC SUBORDINATION.

Organic Differentiation and Integration.—We have seen in the preceding chapter that the highest organic development is the most complete physiological division of labour, and the most perfect physiological centralization. In the lowest organic species, and in the germs of the highest, the parts are all alike and all independent of each other; in the mature forms of the highest species the parts are all different, and the whole organism is bound together into one system, with all its parts mutually dependent. To speak technically, organic progress consists in increasing *differentiation* and increasing *integration.*

Organic Dependence and Subordination.—Besides these, there are within the organism relations of *dependence* and of *subordination,* which we have now to describe. Before stating the relation of organic dependence we must go back to the inorganic sciences.

Similar Relations in the Inorganic World.—Whatever exists, so far as is known, or can be known, to us, exists in space; and whatever acts, acts in time. Consequently the properties of space and time are conditions of all existence and of all action; the laws under which things exist and act cannot be proved, nor even stated, without express or implied reference to the properties of space and time. It results from this, that

mathematics, which is the science of the laws of space and time, is the necessary ground of physical science. To take the very simplest instances: it would be impossible to prove, or even to state, the law of the parallelogram of forces, unless the geometrical properties of the parallelogram were known; and it would be impossible to prove, or to state, the law that the energy due to a moving body is proportional to the second power of its velocity, unless the nature of powers and roots were known. Mathematics is thus necessary as a foundation for dynamics.

Dynamics the Basis of Physical Science.—Among physical laws, the most general are those of force: the laws of force, or, as they are generally called, the laws of motion, are the only laws which are true of all action whatever. Consequently, dynamics is necessarily the basis of physical science: or, in other words, the theory of force is necessary as a basis for the sciences of material things.[1]

The sciences of sound, light, heat, electricity, and magnetism, are merely particular cases of dynamics, being applications of the theory of force to special kinds of actions.

The laws of force apply to all the actions of all matter; but there is a great variety of laws that apply only to those actions, or functions, which are characteristic of particular kinds of matter: I mean the laws of chemistry. The laws of chemistry depend on those of heat and electricity in a very great degree; so decided indeed is the dependence, that it would be impossible so much as to state many of the most important chemical laws, unless the elementary laws of heat and electricity were taken as known.

[1] It may be said that I contradict myself in calling mathematics the *ground* of physical science, and dynamics its *basis*. There is, however, no contradiction. Dynamics is a part of physical science, but mathematics is not. Physical science is built on mathematics, as a building on the ground; the other parts of physical science are based on dynamics, as the higher parts of a building on its base.

I attach no importance to these metaphors, but I wish to show that I have not fallen into any inconsistency.

Basis of Biology in Physics and Chemistry.—Finally, the properties of living organisms, and their peculiar actions, in a great degree depend on the general properties of force, and on the special properties of the chemical substances of which the food of the organism, and the organism itself, are composed. Vital properties are certainly more than mere resultants from physical and chemical ones, but life does not suspend the ordinary physical and chemical properties of the substances in the organism; on the contrary, it works through them. Consequently, the action of life depends on the properties of the materials it has to work with; and it is impossible to understand the nutritive functions of organisms, without some previous knowledge of chemistry. It would have been impossible, for instance, to explain the nature of respiration, which is a slow combustion, unless the nature of combustion had first been discovered.

Series of Sciences.—So that we have this series of sciences, each dependent on the preceding:—

1. Mathematics, or the science of the properties of space and time.
2. Dynamics, or the science of the laws of force in general.
3. The secondary dynamical sciences, being those of sound, light, heat, electricity, and magnetism; all of which are particular applications of dynamical theory.
4. Chemistry, or the science of the special properties of particular kinds of matter.
5. Finally, Biology, or the science of the properties of living beings.

Dependence of one Science on another.—In this series each member is dependent on that which goes before it, but independent of that which comes after it. Biology is dependent on chemistry, because the actions of life on the substances in the organism cannot be understood unless the properties of the substances themselves are known first. Chemistry is dependent on the secondary dynamical sciences, because its

laws imply those of heat and electricity, and could not be understood without them. The secondary dynamical sciences are dependent on general dynamics, of which they are but particular cases. And lastly, dynamics depends on mathematics, without which it cannot make a single step in reasoning.

The Dependence is not Reciprocal.—This dependence is not reciprocal. The truths of mathematics do not in any way depend on those of dynamics for their proof. The truths of general dynamics are true, independently of those of the secondary, or special, dynamical sciences. The laws of the secondary dynamical sciences are true, independently of those of chemistry, and can be understood without them. And the laws of chemistry are true, independently of those of life, and can be understood without them.[1] Thus the series resembles a building of several stories, each of which rests on that below it.

Obligation to Comte.—So far, I have taken these ideas about the dependence of the properties of things, the one on the other, from Comte's *Positive Philosophy*.[2] What follows, though I claim no originality for its substance, has not, so far as I am aware, been stated in a systematic form before.

Dependence of Mental on Animal, and of Animal on Vegetative Life.—We have seen that in inorganic nature, and up to the laws of life, there is a relation of dependence of the laws of one

[1] It may be objected, that this is wrong in point of fact; it may be said that chemical laws are implied in the theory of electric currents, and biological laws in organic chemistry. I reply, that electro-chemistry does no doubt imply chemical laws, and may be regarded as a branch of chemistry, but the whole theory of electro-statics and electro-dynamics may be stated without any chemical knowledge being needed. And as to organic compounds, chemistry works with them just as if they were mineral substances.

[2] See Harriet Martineau's condensed translation of Comte's *Positive Philosophy*, vol. i. chap. ii. I have read Comte only in the above-mentioned translation, which I believe is thoroughly trustworthy. The series I have drawn in the text differs from Comte's in detail, but is the same in principle.

science on those of another, which dependence is not reciprocal. The same relation is continued between the different laws of life: animal or motor life depends on vegetative or nutritive life; and mental life depends on animal life. And among these also, the dependence is not reciprocal: vegetative life may exist without animal life, and animal life may exist without mental life. Mental life depends on animal life, and animal life depends on vegetative life, just as vegetative life depends on chemical properties, and chemical properties depend on those of heat and electricity. These are facts of observation. Throughout the whole vegetable kingdom we see vegetative life without animal life; and throughout a great part of the animal kingdom we see energetic animal life with scarcely a trace of mental life. But the converse is impossible; there is not, nor under the laws of life can there be, any such thing as animal life without vegetative or nutritive life for its basis; or mental life, without animal life as its basis. It is a consequence of this relation, that the animal life may be almost, if not totally, suspended in sleep; but the vegetative life cannot be suspended for a moment without death. And another very remarkable consequence of the same relation has been experimentally ascertained; namely, that it is possible to extinguish the mental life, and in a great degree the animal life, of an animal, by removing the parts of the brain that minister thereto, while the organs of the vegetative life continue to perform their functions for a considerable time. Of course in this experiment, as well as in sleep, the involuntary muscles of the heart and lungs continue to act, as on their action that of the vegetative life depends.

The Series continued.—We may now thus continue the series that we saw to exist from the laws of space and time up to those of life, so as to include the three ascending degrees of life itself; each term of the series being dependent on those which go before it, but independent of those which come after it:—

1. The properties of space and time: mathematics.

2. The laws of force: dynamics.

3. Special cases of the laws of force: sound, radiance, heat, electricity, and magnetism.

4. The properties of particular kinds of matter: chemistry.

5. The laws of vegetative life.

6. The laws of animal life.

7. The laws of mental life.

But though the dependence of animal life on vegetative life is of the same kind with the other laws of dependence that I have stated, yet it is not practically possible to treat of them apart, as the subjects of distinct sciences. The old distinction of zoology and botany must no doubt be always necessary in classification, but it would be impossible to treat the physiology of the vegetative life, and that of the animal life, as distinct sciences.

Subordination of Organic Functions.—We have seen that the relation of *dependence* of one group of properties, or functions, on another, holds both in inorganic matter and in life. But when we come to vital functions, we find a different though parallel relation, unlike any in the inorganic world. I mean the *subordination* of one function to another: one function working through another. As we have already seen, life acts through the physical and chemical properties of matter; and it is equally true that the conscious functions, or those of the mind, act through the unconscious ones.

Matter Subordinate to Life, and Life to Mind.—Life, as we have seen, does not suspend the ordinary laws of matter and energy; life works in accordance with those laws and through them, directing their forces to the attainment of ends which they could not have attained of themselves. Thus, though life is so completely *dependent* on the ordinary properties of matter that it could not exist, nor even be conceived to exist, without them; yet life makes those properties *subordinate* to its own purposes. Exactly parallel to this is the relation of the mind

to the unconscious life. The mind is *dependent* for its existence on the unconscious life: mind is a function of the nervous system; and the primary purpose of the nerves, as we have seen in the preceding chapter, is to enable the muscles to work together. But mind has the power of making the unconscious life *subordinate* to its purposes.

This last statement will perhaps be scarcely intelligible. It may be thought that whether the mind works in thought or voluntary muscular action, all mentally directed action is conscious; and that the only unconscious life is the vegetative life, which is not under the direct control of the mind at all. This, however, would be a mistaken view. Paradoxical as it may sound, it is a simple truth that muscular action is itself unconscious. We produce the motion of a particular set of muscles—those of the legs, or hands, or mouth, for instance—by a conscious mental determination; we become aware that they move as we intend, by means of the "muscular sense," which is produced in muscles by their action. But between the conscious mental determination and the sense of muscular action, there is an intermediate link of which we are unconscious; namely, the special combination of muscles which is needed to effect the movement we intend. Of this we know nothing whatever except what anatomy teaches us; we effect these combinations by an unconscious instinct. Were consciousness of the required muscular combinations necessary before we could make the combinations, in the same way that, for instance, consciousness of the meaning of words is necessary in order to use the words with accuracy, we could not perform any muscular movement until we had learned the anatomy of the muscles. It is indeed scarcely a metaphor to say that the brain gives its orders to the muscles without knowing the details of the way in which its orders are to be executed. An equally clear proof of the essentially unconscious nature of muscular action is afforded by the fact, that when any set of muscles, especially those used in walking, is set in motion by a determination of the will, and the attention afterwards withdrawn

from their action in consequence of the mind falling into a state of abstraction or reverie, the action of the muscles often continues independently of consciousness or will. And, what is a fact of the same kind, if nervous connection between the brain and the lower extremities is cut off by accidental injury to the spine in man, or by purposely cutting through the spinal cord in an animal, irritation applied to the feet causes no sensation, but produces convulsive movements in the legs, of which the patient is unconscious.[1]

Summary.—To sum up what has been said :—The higher functions are *dependent* on the lower ones; the vital functions are dependent on the inorganic, and the conscious, or mental functions, on the unconscious; but this dependence is not reciprocal. And the lower functions are *subordinate* to the higher ones, which work through them; the unconscious functions are subordinate to the conscious, and the inorganic functions to the organic; and this subordination never becomes reciprocal.

Dependence necessary: Subordination not so.—It is to be observed that the dependence of functions one on the other is necessary and constant; the conscious functions are always and necessarily dependent on the unconscious ones, and life is always dependent on matter. But the subordination of functions one to the other is neither necessary nor constant; the mind often loses its control of the body, and life often loses its control of matter. When the control of the higher functions over the lower, and the subordination of the lower to the higher, are weakened, the result is disease; when they are destroyed, the result is death.

[1] Carpenter's *Human Physiology*, p. 674.

CHAPTER VIII.

ORGANIC FUNCTIONS.

Classification of Organic Functions.—In the preceding chapter I have classed the organic functions as vegetative, or nutritive; animal, or motor; and mental. The vegetative and animal functions I have classed together as unconscious, in opposition to the mental, which are conscious. These distinctions may be most conveniently stated in the following tabular form:—

Unconscious functions .	Vegetative, or nutritive. Animal, or motor.
Conscious functions . .	Mental.

Different Classifications for Different Purposes.—In speaking of the same subject, however, it is often necessary to adopt different classifications at different times, according as we regard it from different points of view. In the present chapter I shall adopt a classification of organic functions which is not based, like the former one, on their obvious connections. That which I am going to use is intended, on the contrary, to show the way in which one function is developed out of another. The law of the development of organisms, as we have seen, is that they are developed out of simple germs, and that the parts are gradually differentiated the one from the other. The same is true of functions;—functions also are developed by gradual differentiation.

Chemical Functions.—Let us speak of the vegetative functions first. The primary vegetative function, which is the ground and

condition of all other vital functions whatever, is the decomposition, by plants, of water and carbonic acid, and the formation of organic compounds. This function is in its results a purely chemical one, though it produces combinations which no chemistry but that of the living vegetable organism can possibly produce.[1] The power of decomposing carbonic acid, and probably water also, is peculiar to the vegetable kingdom, though not universal in it.[2] Animals cannot decompose carbonic acid, and consequently cannot form the primary, or first-formed, organic compounds for themselves ; but they effect various transformations in the organic compounds which they receive in their vegetable food. Some of these transformations may perhaps be due to the ordinary chemical forces, acting as they might act in a laboratory; but some are certainly due to a peculiar vital action, controlling the chemical forces. This is eminently the case in secretion.[3]

Structural Functions.—Formation of Tissue.—The next vegetative function consists in the arrangement of the organic compounds so as to form tissue. As already stated,[4] the simplest tissues are mostly cellular. Many organisms, as for instance the lowest Algæ, consist of but a single cell, which propagates by spontaneous division. But in others the cells, after dividing, do not separate, but remain together; and thus cellular tissue is formed. The unicellular and multicellular forms of Algæ graduate into each other, and the Algæ in general consist of a mass of cellular tissue, with little further differentiation.

Cells, in the various parts of various organisms, undergo endless modifications, both in form, and by acquiring the power,

[1] See p. 7.

[2] If there are whole tribes of vegetables which, like animals, do not decompose carbonic acid, if vegetables have motor actions like animals, and if the lowest classes of animals have no muscles nor nerves, what is the distinction between the kingdoms? I reply, that I do not believe there is any absolute and certain distinction whatever.

[3] See p. 9.

[4] See p. 56.

as stated above, of separating different substances from the sap or blood. Accordingly, the next differentiation consists in the acquisition of different characters by different masses of cells, so as to form different tissues: as, for instance, soft leafy substance and hard woody fibre, in plants; and muscle, nerve, and bone, in animals.

Growth and Development.—The formation of tissues constitutes growth, and the differentiation of tissues the one from the other constitutes development. It is important to observe that growth and development are not the same thing; they do not imply each other, and do not necessarily go on together—indeed, there is frequently an antagonism between them; rapid growth and rapid development appear, at least in certain cases, to be incompatible. Thus, flowers are more highly developed than leaf-bearing branches; and flower-bearing branches are always found to have lost something of the indefinite power of growth that belongs to leaf-bearing ones; and if they are supplied with abundant nourishment, so as to cause them to grow rapidly, they often cease to bear flowers, and are changed back into leaf-bearing branches.[1] A still more remarkable instance of the same kind is that of the worm-like larvæ of some insects, which at first feed voraciously and grow rapidly, forming comparatively simple and undifferentiated structures: but growth ceases when further development begins; growth ceases when the larva enters into the chrysalis state, and all the vital energies are employed in the work of development, which consists in transforming the comparatively undifferentiated tissues of the larva into the highly differentiated tissues of the perfect insect. And

[1] If I understand Dr. Beale, he believes rapidly-growing morbid growths, of the cancerous type, to be caused by cellular growth being in such excess as to destroy the power of development. (See Beale's edition of Todd and Bowman's *Physiology*, pp. 92, 130.) It is known that cancer consists of "fungous" cellular tissue of very low organization. It is very interesting, and to my mind satisfactory, thus to find this most fearful of all classes of disease traceable, like commoner diseases, to a disturbance in the balance, or harmonious action, of the different vital functions.

not only so, but the insect becomes inactive: motion ceases as well as growth, in order apparently that no energy may be spared from the work of development. As already remarked,[1] it is scarcely possible to doubt that some transformation of energy takes place in the process of development and organization.

Formation of Organs.—The tissues which are differentiated from each other combine into organs. In some cases there is no distinction between tissue-formation and organ-formation. The shell of a mollusc, for instance, is at once a peculiar tissue and a peculiar organ. But in the highest organization each tissue is found in many organs, and each organ consists of many tissues. Muscle, nerve, and bone, for instance, are found alike in the head, in the limbs, and along the spine of man. It is self-evident that the formation of organic compounds must be anterior to any formation of tissues or organs. But it cannot, I think, be said that the formation either of tissues or of organs is in any sense anterior to the other. It is to be remembered also, that, as already stated, there are some tissues, at least in animals, which do not originate in cells, but are formed by the direct transformation of structureless sarcode.[2]

Classification of the Vegetative Functions.—From the point of view which has been taken in the last few paragraphs, the vegetative functions may be classified as

Chemical . .	Formation of organic compounds.
Structural .	Formation of tissue. Formation of organs.

Animal Functions.—We now come to the animal functions, which essentially consist in the transformation of energy.[3] As I aim only at drawing an outline, not at filling it up (which, indeed, in the present state of science, no one, probably, is competent to do), I shall say nothing of the production of heat,

[1] See p. 19. [2] See p. 56.
[3] See the Chapter on "The Dynamics of Life" (Chapter II.).

electricity, and light, by animals; I shall speak, as in the preceding chapter, only of the motor functions, which are the characteristic ones of unconscious animal life; and of the sensory, conscious, and mental functions.

Four Grades of the Motor Function.—In the ascending scale of nature, there are four grades of the motor function, differing from each other according to the circumstances under which the transformation of vital into motor energy is determined.

Spontaneous Motion.—The first of these may be called the spontaneous. To this class belong the circulation, or rather rotation, of the almost fluid contents of vegetable cells, which is often to be seen under the microscope; the motions of the germs of low aquatic organisms, vegetable as well as animal, through the water (which have often caused them to be mistaken for microscopic animals); and that "ciliary" motion, which is the only motor action of sponges, and is extremely general in the animal kingdom. Motions of this class are found where there is no nervous system, as in sponges: and even where there is a nervous system they are quite independent of nervous agency, as is proved by the fact that the "cilia" in man and the higher animals continue in motion long after death, and even when they are detached from the body. So far as has been ascertained, they are also independent of any structure, but are simply due to the primary power of living matter to transform energy. No structure has been as yet discovered in the "ciliated cells" of even the highest animals.[1]

[1] Carpenter's *Comparative Physiology*, p. 125. See also Carpenter's *Human Physiology*, p. 855.

Cilia are minute hair-like projections, which are in constant and rapid motion during life. Their use varies according to position: in animalcules and in the Ciliograda, or Ctenophora, they are organs of motion; in very many animals they are used to produce currents in the water, sometimes for the purpose of bringing food, sometimes to keep the respiratory organs bathed with fresh supplies of water. In land animals, their only known function is to produce currents of fluid towards the outlets of the body. If cilia are to be called organs, they are organs the formation of which is independent of any differentiation of the tissue.

Reflex Action or Motion in Response to a Stimulus.—The next kind of motor action is that which is performed in response to a stimulus, and is not accompanied with sensation. This is generally confined to animals, though there are instances of it among plants, as in the sensitive-plant and in Venus's flytrap. The fact that it exists among vegetables proves that it cannot be essentially dependent on nervous action ; and a similar proof is afforded by the Hydrozoa among animals, which have no vestige of a nervous system, yet spontaneously close on their food when it touches the tentacles. And all muscular fibre appears to have the power of contracting in response to various kinds of stimuli, such as electrical excitement,[1] and the application of some poisons, as well as to the stimulus of a flow of nervous energy. But where there is a nervous system, all muscular action appears to be normally produced by nervous agency. This is true even of the action of the heart, which has a nervous system of its own. When motion takes place in response to a stimulus and through nervous agency, the mechanism is as follows: Every nerve-fibre is connected, at least at one extremity, with a ganglion. Different nerve-fibres have different functions, according to the organs with which they are connected at their *outer* terminations (their ganglia being called their *inner* terminations): some are *centripetal*, and transmit stimuli from without inwards to their ganglia; others are *centrifugal*, and transmit motor impulses from the ganglia outwards to the muscles. All motor action which is determined by nervous agency is a complex fact, involving the participation of at least two nerve-fibres and a ganglion. When motion is caused by a stimulus, the stimulus—which may consist, for instance, in the contact of something that irritates the skin, or in the presence of food in the mouth—produces a flow of nervous energy along the nearest centripetal fibre to its ganglion. Some action takes place in the ganglion which determines the flow of a current of

[1] Thus in Helmholtz's experiment (p. 62) to determine the velocity of the nervous current, electricity is seen to be capable of acting on muscle directly, as well as of acting on it through the nerves; causing the muscle to contract in either case.

nervous energy outwards, along a centrifugal or motor nerve-fibre to the muscle in which the motion is to be produced, in order to make the right response to the stimulus.

Such actions as these are called reflex, the nervous action being, as it were, reflected back from the ganglion. There can be scarcely a doubt that this is the only kind of nervous action in those animals which have a nervous system in its most rudimentary form—as, for instance, in the lower mollusca. As we ascend in the animal scale, the proportion of purely reflex actions appears to become constantly smaller; but even in man those muscular actions which minister directly to the vegetative life are of this kind. The actions of the heart, lungs, and stomach are reflex, being independent of sensation or will: the stimulus to action is given in the heart by the flowing in of the blood; in the lungs, by the flowing in of the air; in the stomach, by the contact of the food. And actions which are normally performed in obedience to sensation or will may become reflex: thus, if the spinal cord (which is a vast bundle of nerve-fibres, accompanied with ganglionic cells) is so injured as to destroy all nervous connection between the lower extremities and the brain, the lower extremities cease to have any sensation or to be under the control of the will; but the ganglionic masses of the spinal cord act as a "reflex centre" for them; and if the centripetal nerves are excited, as by tickling the soles of the feet, the spinal cord, on receiving the unfelt stimulus from the centripetal nerves, will reflect it back along the corresponding centrifugal nerves in the form of a motor impulse, producing convulsive motions of which the patient is totally unconscious.

Consensual Action.—Next is what Dr. Carpenter calls consensual action: that is to say, muscular action depending on sensation, but involuntary; such as closing the eyes against a flash of light, or shrinking from the contact of anything that cuts or burns. Both reflex and consensual action are in response to a stimulus; but reflex action, as we have seen, is independent

of any sensation, while the stimulus to consensual action consists in sensation.[1]

Difference between Sentient and Insentient Ganglia.—We thus see that some ganglia are sentient, while others are merely reflex :—that is to say, sensation arises in some ganglia when they are acted on by their nerve-fibres, while others are without this wondrous property. The microscope does not reveal any difference between the ganglia, or between the nerve-fibres, which are thus so unlike in their powers; and it appears most probable that this unlikeness of powers does not depend on any difference between the nerves and ganglia themselves, but on their connections with other nerves and ganglia, namely those of the brain.

Voluntary Action.—Last and highest is voluntary muscular action. This, also, as well as reflex and consensual action, depends on the stimulus of currents of nervous energy acting on the ganglia which are in communication with the motor nerves; but in the case of voluntary action, the exciting currents proceed, not, as in the other two cases, from the outer extremities of nerve-fibres, but from within the brain itself. We shall have to say more on this subject when we come to treat of Mind.

No line can be drawn between consensual and voluntary action. Many actions, such as closing the eyes or coughing, may be either the one or the other; and an action that was at first voluntary may become consensual from habit; as, for instance, the act of walking, which, though it has to be almost consciously learned by the child, soon comes to be carried on in response to the sensation of touching the ground with the feet, without needing a fresh determination of the will at every step. It is proved by the facts of instinct that many actions which are voluntary in man are consensual in many, if not all, of the

[1] Some writers call consensual action a species of reflex action, but it is better to keep the terms distinct.

lower animals. Thus, chickens pick up grains, and ducks run to the water, the moment they are out of the egg.

Summary.—We thus enumerate four kinds of motor action in organisms, according to the way in which it is produced, as follows:—

1st. Spontaneous.
2d. Produced by an unfelt stimulus, or reflex.
3d. Produced by a felt stimulus, or consensual.
4th. Voluntary.

It is interesting to observe how these functions are successively added, the one to the other, in the ascending organic scale. Thus, all organisms whatever perform spontaneous motions: all animals, except perhaps some of the very lowest, move in response to a stimulus: all sentient animals move in response to sensations, and no doubt all animals that have any mental power higher than mere sensation are capable of voluntary motion.

Sensory Functions.—We now come to the sensory functions. We have seen that the nervous system is, essentially and primarily, a part of the animal apparatus for the transformation of energy. Every action of the nerves, as well as of the muscles, is, beyond doubt, accompanied by a transformation of energy. In sensation and thought the transformation of vital energy is probably into heat.

Mind.—We have enumerated four successive gradations of the motor functions. The gradations of the sensory functions are almost infinite: beginning with simple sensation, and going on through those functions of memory, perception, and thought, which constitute Mind. All these have their starting-point in sensation; they consist of simple elements, which, however, form endlessly varied combinations. In the logical order, this would be the place for a treatise on mental science; but it is more convenient to keep to the customary order, and, so far as

possible, to treat of mental science apart, and after biology; and for the present I enumerate all the sensory functions under the two heads of Sensation and Mind.

Tabular Summary.—All the organic functions may consequently be enumerated in the following tabular form:—

Formative or vegetative functions, essentially consisting in the transformation of matter.	Chemical.	Formation of organic compounds.
	Structural.	Formation of tissue. Formation of organs.
Animal functions, essentially consisting in the transformation of energy.	Motor.	Spontaneous. Reflex. Consensual. Voluntary.
	Sensory.	Sensation. Mind.

Development of Functions by Differentiation.—I hope I have now said enough to make intelligible the statement at the beginning of this chapter, that vital functions are developed one out of the other by gradual differentiation. Within each of the three groups of functions—formative, motor, and sensory—there is so perfect a gradation between the various kinds, or rather the various grades, of functions, that we may easily believe one to be developed out of the other in the ascending scale. In the vegetative or formative series, the first and simplest functions are the chemical ones. Above these are the structural functions, the lowest and simplest of which is the formation of cells. Now, cells are formed by a chemical differentiation between the constituents of the inside and the outside of the cell; so that the chemical function here passes into the structural one. And a gradation is manifestly possible from the formation of the simplest cellular tissue to that of the most complex organ. In the motor series, the gradation is decided: it is impossible to say where the one grade ends and the other begins. The same is equally true of the sensory, though perhaps less obvious: but I defer this part of my subject till I come to treat formally of Mind.

Gradation between the Formative and the Motor Functions.—It is not easy to see any possibility of a gradation between the motor and the sensory functions, but there is perhaps a gradation between the formative and the motor. The Foraminifera, and some other Rhizopods, put forth projections of the sarcode substance of the body, called pseudopodia, which are, at least as to function, temporary tentacles. May not these be truly homologous with the permanent tentacles of the Hydrozoa? If so, the putting forth and retraction of the pseudopodia, which are manifestly motor actions, are also to be classed as formative, forming the transition from the formative to the motor functions. What supports this conjecture is the fact, that in *gromia* the pseudopodia are only formed at one end, but in *amœba* they are formed on any part of the surface of the body; just as in *hydra* the tentacles all form a ring round the mouth, but in some of the compound Hydrozoa there are tentacles on various parts. Sir Wyville Thomson appears to share this view. He says: "I am strongly inclined to regard cilia as locomotive pseudopodia, and to consider them special to the sarcode [living but structureless] element."[1] Cilia are certainly in some degree permanent organs.

[1] "Embryology of the Echinodermata," *Natural History Review*, Oct. 1864.

CHAPTER IX.

HABIT AND VARIATION.

Definition of Habit.—The definition of habit, and its primary law, is that all vital actions tend to repeat themselves; or, if they are not such as can repeat themselves, they tend to become easier on repetition.

All Vital Actions become Habitual.—All vital actions whatever come under the laws of habit: and none but vital actions do so. By *vital* actions I mean all those actions which organisms perform in virtue of being alive: and when I speak of *actions,* I include all functions, even those in which the organism is usually said to be passive, as in sensation.

Habit and Instinct.—We generally use the word "habit" with special reference to the mysterious border-land between the conscious and the unconscious functions. Thus we say, that such an action as using some particular tool is conscious at first, and afterwards becomes habitual. This is one of the most important cases of the law of habit, and for the purposes of human education it is all-important: but it is only one case of the law. Among animals in the wild state there is a great variety of instincts to which this explanation will not apply. To mention that which Darwin justly calls "the most wonderful of all known instincts," we cannot suppose that the bee, in building its hexagonal cells, has, or ever

had, any conscious knowledge of those geometrical properties of the hexagon which make it the most suitable form at once for convenience and for the economical use of wax. If we admit, as I think we must, that this and other purely unconscious instincts are cases of habit, the definition of the word habit must be greatly extended. Habitual actions, under any possible definition, include all mental and mentally determined actions which are not purely voluntary. But, if we are to extend the definition of habit so as to include under the denomination of habitual such purely unconscious instincts as that of the bee, we must include under that denomination all motor actions whatever that are characteristic either of organic species or of particular individuals. And this is true not of the motor actions of animals only, but also of those of vegetables: for instance, those remarkable motions of some climbing plants that Darwin has lately described, the tendrils of which swing about until they touch something, and then clasp themselves round it. Here there is no possibility of conscious purpose on the part of the plant itself, and yet the motions of its tendrils are as truly habitual and instinctive as those of a serpent's body, or of a chameleon's feet and tail, in grasping the branches that they climb. Thus all mental and all motor actions are to be classed as habitual, excepting only those which are directed by a voluntary impulse in pursuit of a conscious purpose.

Formative Habits.—But a still more extensive use of the word "habit" is sanctioned by usage, and, in my opinion, with perfect accuracy. Physicians speak of a habit of body; and botanists speak of the habit of a plant, meaning by that expression such characters as whether the stem is herbaceous or woody, whether the leaves are fleshy or thin, &c. Characters of this kind belong not to the motor but to the formative functions—not to the animal, but to the vegetative life; yet I think it is perfectly accurate to class such characters as habits, and to say that they come under the laws of habit. I believe that all classes of vital functions come under these laws, whether

formative, motor, or sensory;—in other words, whether vegetative, animal, or mental. As we have seen at the end of the preceding chapter, formative and motor actions are so closely connected that they graduate into each other; and another instance of their connection may be mentioned here:—"*Ampelopsis quinquefolia,* or the Virginian creeper, avoids the light, uniformly seeking dark crevices on broad flat surfaces, as a wall, a rock, or the trunk of a tree. The tips of the tendrils, brought into contact with such a surface, swell out, and form in a few days those well-known discs or cushions by which the plant firmly adheres to its support."[1] The moving of the tendrils in search of some suitable dark crevice in order to fix themselves is a motor action; the formation of the cushions is a formative action; yet both are characteristics of the species, and the one is as much a habit as the other.

Apparent Cases of Habit in the Inorganic World.—It may appear that the law of habit is in no way peculiar to the actions of living beings: for there are many inorganic actions that tend to repeat themselves, and to become easier on repetition. For instance: flowing water generally makes a channel for itself, and tends to flow afterwards in the same channel; and if a piece of paper has been once folded, it is easier to fold it again in the same folds than in new ones. But there is a fundamental difference between such cases and all true cases of vital habit. The cases just mentioned are cases in which the direction of action is determined by mere change of form: the water tends to flow in the channels, because their form is suitable; the paper tends to lie in particular folds, because it has acquired their form. But let the channels be filled up, or let the folds be taken out of the paper by hot pressure, and these tendencies will be lost.

[1] From a notice in the *Quarterly Journal of Science*, April 1866, of a paper of Mr. Darwin's, on "Motion and Sensitiveness in Climbing Plants." For more detailed information respecting the habits of Ampelopsis, see Darwin's work on *The Movements and Habits of Climbing Plants*, p. 144.

Difference between these and True or Organic Habits: Hereditary Transmission.—But, it may be said, may not organic habits be the result of changes of the same kind? May not the formative, motor, and mental characteristics of every living species and individual be due to peculiarities of structure so minute and subtle as to elude the microscope?[1]

I reply, that this would be a most plausible view if habitual characters were confined to the individuals in which they are formed. But this is not the case: all habits (that is to say, according to my definition of the word "habit," all characters whatever) become, or tend to become, hereditary. We have seen that an embryo at the earliest period consists, not of a miniature of the parent form, but of a small mass of germinal matter, without structure or form, but having an inherited tendency to reproduce the structure, form, and all the habitual characters of its parents. This truth can be expressed in the language of the theory of habit only by saying that every habitual tendency passes, or tends to pass, from the organ which is its seat (as, for instance, the brain is the seat of mental habits) into the germinal matter of the body: and when a portion of that germinal matter is thrown off in order to produce a new individual, it imparts its habitual tendencies to the new individual. I have already admitted[2] that there may probably be structure in germinal matter which, by reason of the transparency of the matter and the minuteness of the structure, can never be made visible. But if it were proved that every peculiar property of the germinal matter of any particular individual or species were correlated with some peculiarity of structure, this would only push the difficulty back by one step: for it is inconceivable that any mere mechanism of molecules could have the power of reproduction. Structure and organization must be in all cases the effect, and not the cause, of vital powers.

[1] This view of mental habits as depending on acquired peculiarities of nervous structure has been maintained, most ingeniously and elaborately, by Professor Bain. (See the *Fortnightly Review*, 1st February, 1866.)

[2] P. 48.

Inherited Characters appear sometimes at the same Age as in the Parent, sometimes Earlier.—When any peculiar tendency is inherited, it sometimes appears in the offspring at the same age at which it appeared in the parent, but sometimes earlier:[1] never, probably, or only in the rarest cases, at a later age. Hereditary diseases afford many instances of both kinds of cases: of the peculiarity reappearing in the child, in some cases at the same age at which it was acquired by the parent, and in some cases at an earlier age.

Instance of Inherited Character.—A remarkable instance of the habit showing itself at an earlier age is the fact of young dogs, the parents of which have been taught to point, themselves sometimes beginning to point the first time they are taken out. The following is a very striking instance of the same kind: "Sir C. Lyell mentions that some Englishmen, engaged in conducting the operations of the Real del Monte Company in Mexico, carried out with them some greyhounds of the best breed to hunt the hares which abound in that country. It was found that the greyhounds could not support the fatigues of a long chase in this attenuated atmosphere, and before they could come up with their prey they lay down gasping for breath; but these same animals have produced whelps, which have grown up, and are not in the least degree incommoded by the want of density in the air, but run down the hares with as much ease as do the fleetest of their race in this country."[2] In this case the power of breathing with facility in a rare atmosphere, which only had a tendency to be produced in the parents, was congenital in the offspring.

Habits are Changeable.—Another most important law of habit must be formally stated, though it is implied in what has been said about the acquisition of new habits. It is, that all

[1] Darwin on the *Origin of Species*, 6th ed. p. 10. (It is from the sixth edition I shall always quote.)

[2] Carpenter's *Comparative Physiology*, p. 987.

habits are in some degree changeable. New habits are constantly produced by change of circumstances, and by education, which indeed is only a special and artificial set of circumstances: and this could not be the case if habits were not in some degree changeable.

Habits are Spontaneously Variable.—But besides the *changeability* of habit as the result of changing circumstances, there is a certain amount of *spontaneous variability* which does not depend—at least not directly—on change of circumstances. No child is exactly like either of its parents, and no two children of the same parents are exactly alike. These differences might be attributed to differences of circumstances acting on the offspring through the parents ; but such an explanation is shown to be at least insufficient, by the fact that the same differences are found to exist between twins, though generally in a somewhat less degree than between other children of the same parents ; and it is obvious that twins have been subjected to precisely the same influences.

Laws of Variation: Habits of Varying: Instance of Acquiring Languages.—Variation appears in some degree to take place according to ascertainable laws. Of these laws we know but little; it is, however, an important truth, that variation does not go on equally in all directions at once, but takes place in particular directions at particular times: in other words, organisms acquire *habits of varying* in particular directions; and these habits of varying are characteristic not only of individuals but of species and genera; perhaps we may say, of whole classes. As an instance of this—not by any means the strongest instance I can think of, but the most familiar—may be mentioned the well-known fact that the acquisition of any power that depends on habit makes it easier to acquire other powers of the same kind: thus, the mastering of one language makes it easier to master other languages. This is not simply a case of a habit perpetuating itself. The knowledge of any language

consists in the habitual connection in the mind between the words of the language and the ideas they represent, so that the one will recall the other without effort; and these connections are different for every different language. But though the habitual connections are different, the habit which is cultivated in acquiring them for one language facilitates their acquisition for another: a habit has been acquired of acquiring a particular kind of habits. This law, that organisms acquire a habit of varying, or, in other words, of altering their habits in particular directions, is shown by Darwin to be true of the formative functions as well as of the motor and mental ones; and he has clearly perceived its great importance in accounting for the origin of species.

Habits are Weakened and Destroyed by Disuse.—Habits, as we have seen, are formed and strengthened by repetition of the acts;—this is only a statement of the elementary law of habit. The converse is also true: habits are weakened, and may at last be destroyed, by discontinuance of the acts; as, for instance, when we forget how to speak a language, or to practise an art, which we once knew but have discontinued.

This is a case of the general Law.—This is not an independent law, but merely a case of the elementary law of habit. The elementary law is, that by acting in any way a habit is formed of acting in that way: and it is a case of that law, that by ceasing so to act, a habit is formed of not so acting; or, what is the same thing in other words, the habit of so acting is lost.

Prominence and Tenacity of Habits.—From these two laws—that habits are strengthened by repetition of the acts, and are weakened by their discontinuance—it follows that the strength of any particular habit, other things being equal, depends on two different factors: one, the length of time during which the habit has been exercised; the other, the shorter or longer time that has elapsed since it has been exercised. The

effect of these two factors, however, is not the same in kind. The *prominence*, or present strength, of any particular habit depends chiefly on its having been recently exercised; but the *tenacity* of a habit, or, in other words, the difficulty of weakening or destroying it by disuse, is a different thing from its present strength, and the two do not stand in any constant proportion to each other. The tenacity of a habit depends on the length of time during which it has been exercised: that is to say, the longer a habit has been in forming and strengthening by exercise, the longer time it will take for it to be weakened or destroyed by disuse. These facts are familiar. Everyone knows that habits of long standing are not easily lost; and the most tenacious habits are those which belong to the species, and have been exercised not merely through a lifetime but through an unknown number of generations. Hereditary characters, indeed, are seldom—probably never—destroyed by disuse during a single generation, though they may be destroyed by disuse during many generations: the domestic fowl and duck, for instance, have nearly lost the power of flight by long-continued disuse. Thus the law of the hereditary transmission of habit is equally true of its destruction as of its formation.

These truths are little more than obvious corollaries from the elementary laws of habit; but on them depend some very remarkable and rather intricate interactions between different habitual characteristics. A habit which has been much exercised during only a short time may be very prominent, but it cannot be very tenacious; and it may be lost by disuse during a period of time which is too short to produce any perceptible effect in destroying a more tenacious though perhaps less prominent habit. Cases of this kind are no doubt difficult to identify, but it certainly is possible that new mental and moral habits, amounting to a change of character, may be acquired as a result of education and circumstances, and may afterwards disappear with advancing age and under new circumstances, while the original, perhaps hereditary, character reappears.

Latent Habits: Reversion.—A tenacious habit may appear to be lost when it is in reality only latent. A latent habit is one which, though not obvious, may at any time reappear; sometimes spontaneously, sometimes by placing the organism in the same circumstances as those which produced the habit at first. It is a well-known instance of this, that when the use of an art or of a language has been laid aside so long that, at the first attempt to recommence it, it appears to be totally lost, a little practice will often prove sufficient to regain it in a mere fraction of the time that would be necessary to learn it if it were really new. This is a case of the rapid reappearance of a latent habit under favouring circumstances.

It is a case of the same kind, that even when a habit does not become hereditary, a tendency to it, or a facility for acquiring it, may become hereditary. Thus, when a young pointer has not inherited the habit of pointing, that habit is nevertheless more easily acquired by him than it would be by a dog whose ancestors had not been taught to point. The fact of the dog's ancestors having learned to point gives the same facility to the dog himself in learning it, which the fact of the man having once learned an art gives him in learning it again.[1]

But the most remarkable instance of the spontaneous reappearance of a habit is the reversion of individuals, and, as I believe, of species, to ancestral characters after the lapse of many generations; which, according to general belief, sometimes occurs in the human race, and beyond all question does occur among domesticated breeds of animals.[2] The characters of the breed which have arisen under domestication, and consequently are of later date than those of the species, are *prominent* habits: those of the species which reappear in these cases of reversion are *tenacious* habits, which may, as it were, be overlaid and concealed by the later acquired ones for a great

[1] See Bain on *The Emotions and the Will*, Appendix C.

[2] See Darwin's *Variation of Animals and Plants under Domestication.* I shall have to quote many of his facts in the following chapter.

number of generations, and yet reappear at last. We shall have to speak, further on, of the importance of this class of facts in accounting for the characters of species.

The Laws of Habit are Elementary Laws of Life.—In the chapter on the Dynamics of Life we have seen reason to conclude that the differentia of life consists in certain powers, which all living beings possess, of transforming matter and energy. Except the laws of those transformations, I believe the elementary laws of habit are the only laws of life which are at once elementary and universal. I regard these as ultimate laws, incapable of being referred to any others.

Active Habits Strengthen, Passive Impressions Weaken, by Repetition: Instance of the effect of an Unaccustomed Sound.—It is an important result of the laws of habit, that while active habits are strengthened by the repetition of the act, passive impressions are weakened by the repetition of the impression.[1] Both of these facts are familiar: everyone knows that being habituated, or accustomed, is an explanation alike of being able to do what an unaccustomed person could not do—as, for instance, to execute a difficult piece of music; and of being able to resist what an unaccustomed person would have great difficulty in resisting, such as great heat or cold, and impressions of particular kinds of horror or fear. It might appear that the weakening of impressions by repetition is the result of a distinct law, opposite in its character to the general law of habit; but it is in reality a case of that law. A passive impression becomes weaker by repetition, because the organism acquires the habit of not responding to it. A passive impression is defined as one which is not followed by action. An impression which is not followed by action differs from one which is followed by action, not in the nature of the impression itself, but in the response which the organism makes to it. The same

[1] So far as I am aware, this remark was first made in Butler's *Analogy of Religion*.

impression, acting on two similar organisms, may, according to circumstances, remain a merely passive impression on the one, and may become an active stimulus to the other. To mention a familiar instance: two men hear the same loud bell in the morning; the one is accustomed to awake and get up at the sound, and he awakes; the other is accustomed to disregard it, and he disregards it and sleeps through it.[1] This view is supported by the fact that it is possible to increase the strength of merely passive feelings—feelings, that is, which do not lead, and are not meant to lead, to action—by the habit of brooding over them; and without so much mental action as is implied in brooding, it is possible to give a mastery over the mind to the passive emotions, especially to fear, merely by acquiring a habit of yielding to it.[2]

The same is true of the Unconscious Life. Effect of Medicines and Stimulants. Action of the Heart under a Stimulus.—The law of passive impressions weakening by repetition, while active habits strengthen from the same cause, is not confined to mental and voluntary actions, but has its foundation far down in the unconscious life. One instance of this is the well-known fact that the power of medicines and stimulants is diminished by constant use. Another and very remarkable instance of the law is the way in which the heart responds to a stimulus; such as a blow, or a sudden fright, or an electric shock. The first effect of a stimulus on the heart is to cause a momentary cessation, or at least slackening, of its action. If the shock is violent enough, it causes death; but otherwise the effect passes away, and is followed by a quickening of the heart's action—the well-known beating of the heart produced by a shock. If the stimulus is repeated, supposing its intensity to be the same, its effect will become less with every repetition,[3] showing that the

[1] I have met with this illustration of the law somewhere in Whately's writings.

[2] See Bishop Fitzgerald's Note B to Chap. V. of Butler's *Analogy of Religion*.

[3] Claude Bernard, in the *Revue des Deux Mondes*, March 1, 1865. The stimulus used in such experiments is that of an electric current sent through the pneumogastric nerve. The heart, in relaxing under a stimulus, acts differently from

heart is acquiring the habit of not making any response to it—just like the sleeper who acquires the habit of making no response to the bell.

General Law respecting Passive Impressions. Instance of Climbing Plants.—From such instances as these—which are clearly not exceptional but normal—we may infer, not only that, as already stated, organisms are capable of acquiring a habit of not responding to stimuli, but also that they always do form such a habit, unless there is some cause to determine them to form the habit of responding. A still more remarkable instance of this law, and one where neither voluntary determination nor nervous action of any kind can come into play, is afforded by the motions of those climbing plants which have been already referred to. It is stated by Darwin, that a thread weighing no more than the 32d of a grain, if placed on a tendril of the *Passiflora gracilis*, will cause it to bend; and merely to touch the tendril with a twig causes it to bend; but if the twig is at once removed, the tendril soon straightens itself. But the contact of other tendrils of the plant, or the falling of drops of rain, do not produce these effects—proving, apparently, that the tendrils have acquired the habit of disregarding these: a wonderful instance of vegetable instinct.[1]

other muscles, which contract under the same; the arteries, which have a muscular coat, contract under a stimulus, such as drawing the point of a needle over the skin without making a scratch; but though this effect is opposite in kind to that produced by a stimulus on the heart, yet, like the latter, it is weakened by repetition (Carpenter's *Human Physiology*, p. 329).

[1] *Quarterly Journal of Science*, April 1866, p. 257. See also Darwin's work on *Climbing Plants*. It is stated in Darwin's work on *Insectivorous Plants*, p. 35, that the tentacles of the leaves of Drosera or Sundew have the same instinct of disregarding the contact of drops of rain, while responding to that of insects. It is possible, however, that the motions of Drosera are guided by something like a sense of smell; for "when living flies are pinned at a distance of half an inch from the apex of the leaf, the leaf bends towards the insect until the glands (on the tentacles) reach it and suck its juices."—Mrs. Treat in the *American Naturalist* for Dec. 1873, quoted in *Nature* for Feb. 26, 1874, p. 332. It is remarkable that the habits of the Mimosa or sensitive plant are in some degree opposite to those of the Passiflora described in the text. "The lightest jet from a syringe instantly caused the leaves of a Mimosa to close: whereas the loop of a thread weighing a

Organs Grow with Exercise.—Organs increase with exercise, not only in functional power, but also in size;[1] while, conversely, organs that are disused, in whole or in part, diminish, not only in functional power, but also in size: and such modifications, like all others, are capable of becoming hereditary. It is difficult to prove that this connexion between the habitual exercise of an organ and its magnitude is true of the organs of the nutritive life, because most of them are incapable of any excessive stimulation without producing disease; but the expansion of the chest, which properly-directed exercise produces, appears to show that it is true of the lungs. It is well known to be true of the muscles; and though the evidence is less direct, it is scarcely possible to doubt that it is so of the organs belonging to the nervous system—that the brain, for instance, is increased in functional power and in size by successive generations of mental cultivation.

The Laws of Habit are true of both Mind and Body.—It will be noticed that the instances of habit quoted have been taken indifferently from among mental and bodily habits, or, as I prefer to say, from among conscious and unconscious habits; showing how the same laws of habit govern both the conscious and the unconscious life.

The Laws of Habit do not account for every particular Habit.—It is to be observed that the laws of habit do not account for the origin of every particular habit. This however is not because of any imperfection in our knowledge of the subject: it is because the laws of habit, by the definition of the word, have to do only with the repetition of actions and the perpetuation of tendencies; but they do not necessarily throw any light on the cause of the first of a series of actions that has become

thirty-second of a grain, when rolled into a ball and placed gently on the glands at the bases of the leaflets of the Mimosa, caused no action."—Darwin on *Climbing Plants*, p. 156.

[1] See Note at end of this Chapter.

habitual;—just as the laws of motion, though they are perfectly well understood, throw no light on the origin of force. We know that in man, and in a less degree among the more intelligent animals, a great variety of actions are capable of becoming habitual that were voluntary in their origin. On this possibility the whole art of education is founded. But this explanation will not apply to the facts of spontaneous variation; nor will it apply to any formative habit whatever, nor to such motor habits as the cell-building instinct of the bee, or the turning and twining instinct of the *Passiflora gracilis*, mentioned above. By the definition of habit that I have adopted, all specific characters are habits; and, in this sense, the question of the origin of particular habits includes the whole vast and enigmatic subject of the origin of species. But, little as that subject is understood, recent research and speculation have let a few rays of light into the darkness.

Summary. Elementary Laws of Habit, with their Corollaries. —We may thus sum up the laws of habit:—

All vital actions—formative, motor, and mental—tend to become habitual.

All characters tend to become hereditary. An acquired character, when transmitted to offspring, appears sometimes at the same age at which it appeared in the parent, sometimes earlier.

All characters are in some degree variable, and particular characters may acquire a habit of varying.

The foregoing three are the elementary laws of habit; the following are derived as corollaries from them:—

Habits, being formed by use, are weakened and destroyed by disuse.

The *prominence* of a habit, or its present strength, depends on its having been *recently* exercised.

The *tenacity* of a habit, or the difficulty of destroying it, depends on its having been *long* exercised.

Consequently, a prominent habit may disappear, while a tenacious, perhaps a hereditary one, survives it.

A habit may become latent and afterwards reappear. The reappearance of habits is sometimes the result of favouring circumstances, sometimes spontaneous. Reversion to ancestral characters is a case of the reappearance of habits.

When a stimulus is responded to, it strengthens in force with repetition; when it is not responded to, it weakens.

Organs strengthen and enlarge with exercise: and, conversely, they weaken and diminish with disuse.

It is now time to consider, in more detail than we have yet done, the manner in which the characters of a race will be modified by changes in the circumstances under which it has to live.

Great and Sudden Changes in the Circumstances of Life are Destructive.—It is a universal law, that the health, and ultimately the life, of any organism whatever will be destroyed by any very great change in external circumstances. The most obvious instances of this law are the familiar facts, that air-breathing animals will die in the water, and water-breathing ones will die in the air. These facts, however, do not throw much light on any law of life, for they admit of a purely physical explanation. It is physically impossible, quite irrespective of any law of life, that a man's lungs should breathe water, or that a fish's gills should breathe air. But, independently of physical reasons like this, all great changes are destructive of health and life. Cold regions and warm ones, moist places and dry ones, have all their own peculiar races of animal and vegetable inhabitants; and those species which are native to one kind of abode will, as a general rule, be destroyed by transplanting to a totally different one. Were it not so, differences of climate would be no barrier to the migrations of species, instead of being, as they often are, the most impassable of all barriers. In many cases we cannot say what is the reason of this inability of organisms to adapt themselves to new circumstances. Sometimes, in all probability, it is in part merely physical: for

instance, animals with a coat only of hair may be unable to endure the cold of those countries where most of the native quadrupeds are clothed with fur. But this kind of reason cannot be given in every case. It is impossible to assign any such merely physical reason for the fact that the European race of man is unable to perpetuate itself in the climate of Bengal. Such facts are to be referred to the laws of habit. We have seen that every organism has a certain power of becoming habituated to impressions. This it does in two different ways: if the impression demands a response, such as to close on its prey or to run away from its enemy, the organism acquires the habit of making the right response; if it does not demand nor admit of any response, the organism acquires the habit of disregarding it. Now, exposure to a different climate from that to which an organism has been accustomed, in some cases no doubt produces a response in the vegetative life—as, for instance, in those animals which acquire a coat of hair better suited to their new abode; and sometimes it produces a response in the motor life, as when it determines a species to acquire the habit of periodical migration. But in many cases—probably in the vast majority—no appropriate response is possible. To use familiar language, nothing can be *done*, and the change—the unaccustomed heat or cold—must be *endured*. The organism must become habituated to the climate—that is to say, must acquire the habit of disregarding the change; and if it cannot do this, the change will destroy its health, and ultimately its life. It may not be sufficient to kill the individual; but if its health is at all injured, and this is not recovered in future generations, the race will die out of its new abode. This kind of adaptability is very different in different species: thus the horse has been successfully introduced by man into every climate, from the equator to Iceland and Siberia: the ass would perish in a very cold climate.

Great Changes of Habit are Possible only by being Gradual. Connexion between these Two Laws.—As just stated, great and

sudden changes of circumstances are destructive, and great and sudden changes of habit are impossible. We may say that great and sudden changes of circumstances are destructive, *because* great and sudden changes of habits are impossible. The belief that these two laws really stand in the mutual relation of cause and effect is confirmed by this further pair of laws, which evidently are similarly related to each other,—that great changes of circumstances are often not destructive, provided they are not sudden; and that great changes of habit are often possible, provided they are not sudden. We may say, as before, that great and gradual changes of circumstances often are not destructive, *because* great and gradual changes of habit are possible. As an instance of a wonderful change that has occurred during the human period, we may mention the dog, which, though naturally carnivorous, has in his domestic state gradually become in great part a vegetable feeder, and has been taught to tend sheep. These changes must have taken many generations to bring about. A carnivorous animal would perish if suddenly put on a vegetable diet: not that it would disagree with him—he would die of hunger sooner than touch it.

Adaptation, how Effected. Active and Passive Habits.—The process of adaptation—or, in other words, the effects of changes of circumstances in producing new habitual characteristics—may now be stated; not indeed in detail, but with some degree of precision. External changes, if of any importance, will either destroy the organism, or cause the organism to acquire new habits, so as to adapt itself to the changes. The new habits will be either active or passive. An animal may, for instance, be placed in a severer climate than that to which it is native: this may take place either from such a change of climate as we know from geological evidence to have taken place in past ages, or from the animal being transported by man and becoming wild in its new abode, or from spontaneous migration; and it is sometimes impossible to say what determines the migrations of

animals.[1] In such a case, as already remarked, the animal, if it becomes adapted to the new climate at all, and is not destroyed by it, may become adapted by acquiring either the passive habit of disregarding the cold, or the active habit of producing warm fur on its skin. Of passive habits, we need say no more; but the subject of the formation of active habits, including formative ones, to meet new circumstances of life, is practically an infinite one. Suppose another instance of the same kind. In consequence of the migrations of the animals that serve as its food, a beast or bird of prey is compelled to change its mode of hunting. It may need keener sight, in order to obtain its new prey: in this case, its sight will be more exercised, and will become stronger; and in the course of some generations its eyes will probably be enlarged. Or it may need a keener sense of smell: in this case the same changes will be effected in its olfactory organs. Or it may need greater fleetness: in that case the muscles of its legs will become stronger and larger; and, what is most important to observe, such a change as this will directly or indirectly affect the form of every part of the body—partly by the direct action of the pressure of the enlarged muscles, modifying the form and position of the other muscles and of the bones—partly also, no doubt, by the increased nutrition demanded by the enlarged muscles diminishing the supply of nutrition to the other parts of the body, and so compelling a diminution of their size.

[1] Migrations sometimes occur in very unexpected ways. The following is from the *Quarterly Journal of Science*, October 1864, p. 701:—

"The sudden occurrence of Pallas's sand-grouse (*Syrrhaptes paradoxus*) over the greater part of Europe has attracted the attention of ornithologists, and Mr. Alfred Newton has collected information which shows that this remarkable bird, hitherto almost unknown to the European fauna, has been met with during the year 1863 in no less than 148 localities in Europe and Great Britain, tracing the invading host through 33° of longitude, from Galicia to Donegal. He regards the proximate cause of this wonderful movement as the natural overflow of the population of *Syrrhaptes*, resulting from its ordinary increase, being a bird which has comparatively few enemies, while its time of incubation is short in comparison with what it is in most ground-feeding birds."

The *Syrrhaptes* is a native of the steppes of Central Asia. The above explanation is most unsatisfactory. Why should the overflow have occurred suddenly?

Beneficial Effect of Slight Changes.—We have seen that great and sudden changes of habit are impossible, and that great and sudden changes of external circumstances are destructive to an organism. Whatever may be the connexion of these two laws with each other (and it is probably very close), their opposites are also true: slight changes of habit are possible, and slight changes of external circumstances are beneficial to organisms. As an instance of the beneficial effect of slight changes of external circumstances may be mentioned the proverbial benefit of "change of air"—that is to say, in reality, change of external circumstances—in renewing the bodily and mental health, especially of sufferers from monotonous, depressing, or exhausting occupation; and the equally well-known benefit of "changing the seed" of cultivated plants—that is to say, bringing seeds and cuttings from a distance, instead of sowing those which have been raised in the same farm or garden.

Benefit of Slight Mixtures of Race.—As Darwin [1] has pointed out, there is a profound connexion between this last-mentioned law and the general law that a slight mixture of race, or "crossing of the breed," tends to promote the health and vigour of the race. This view is supported by the fact that "there is reason to believe, and this was the opinion of that most experienced observer Sir John Sebright, that the evil effects of close interbreeding may be checked by the related individuals being separated during a few generations, and exposed to different conditions of life." [2]

Mixtures of Unlike Races.—Very different races will not mix at all: the pollen of a rose on the stigma of a foxglove, for instance, would produce no more effect than if it were so much dust blown off the road. And between these two extremes of kindred races which are benefited by mixture, and totally distinct races which will not mix at all, there is a wide class of

[1] *Origin of Species*, p. 249.

[2] Darwin's *Variation of Animals and Plants under Domestication*, vol. ii. p. 115.

intermediate cases. Sometimes, when two distinct species of plants are hybridised, seed is produced, but in less abundance than if the plant bearing it had been fertilized with pollen of its own species. Sometimes, among animals, the offspring is vigorous but infertile, and cannot give origin to a hybrid race: the mule, between the horse and the ass, is a well-know instance of this. Sometimes offspring is produced, but is weak, and dies early; sometimes, in the case of birds, without being able to break through the egg.[1]

Slight Changes are Agreeable, Great Ones Disagreeable.—Among conscious organisms, slight changes are agreeable, but great changes painful, or at least disagreeable. This law is a most important one in mental science.

Summary.—We have now enumerated four pairs of laws which, it is scarcely possible to doubt, stand in the closest relation to each other. They are as follow:—

Habits are capable of change; but only a slight change is possible in a short time.

Changes of external circumstances are beneficial to organisms, if they are slight; but injurious if they are great, unless made gradually.

Changes of external circumstances are agreeable to the mind when slight, but disagreeable when great.

Mixture of different races is beneficial to the vigour of the offspring, if the races mixed are but slightly different; but very different races will produce either weak offspring, or infertile offspring, or none at all.

Injurious Effect of Close Breeding.—The desirableness of mixture of race is the converse of the well-known fact that races are injured by constantly breeding in-and-in, that is to say mating too near relatives. The evil of close breeding is so great, that breeders of animals find it worth while to sacrifice some-

[1] *Origin of Species*, p. 251.

thing of purity of race, even with choice races, in order to get a cross. Darwin quotes Sir John Sebright, a great authority on breeding, who says that he has known a race of strong spaniels degenerate, by constant close breeding, into weak and diminutive lapdogs;[1] and the same principle seems to account for many well-attested facts of natural history. The celebrated wild cattle of Chillingham have remained perfectly pure in breed for centuries, as is shown by their uniform cream-colour; and yet it appears certain that their size has much diminished. Islands appear to have a tendency to produce pony—that is to say dwarf—breeds of horses. And the broods of animals bred in aquaria have been sometimes observed in successive generations to become smaller, though continuing healthy.

Sexuality.—What may be called the law of sexuality in organisms—that is to say, the necessity of the union of two unlike individuals of the same species for the purpose of generation—appears to stand in the closest connexion with the law of the beneficial effect of slight mixtures of race;—indeed the former law is probably only a case of the latter. This connexion, and the whole subject of the real nature of generation, can be made manifest only by studying it among the simplest and lowest organisms.

Generation is only a Modification of the General Vital Process.—When the generative process is studied only among the highest organisms, among which it is always sexual, the inference is natural and inevitable that generation is altogether a special function; but its phenomena among the lowest organisms show that it is only a modification of the general vital process of growth and development.

Reproduction of Algæ.—Among the lowest organic forms, reproduction can scarcely be distinguished from growth. Among all Algæ—and indeed throughout the vegetable and animal

[1] Darwin's *Variation of Animals and Plants under Domestication*, vol. i. p. 121.

kingdoms—cells give birth to cells. Among the lowest Algæ in which each individual consists of but a single cell, cells divide into cells; and when they have divided, they separate. Among forms a little higher, they adhere together after dividing, and constitute cellular tissue. When they separate, we call the result propagation; when they adhere, we call it growth: but there is evidently no fundamental difference between the two cases; they are found in nearly allied forms, and indeed they graduate into each other through species in which the adhesion of the cells is very slight.

Simplest Form of Sexual Reproduction in the Lowest Organisms—Separate Evolution of the Sexes in Animals and in Vegetables.—The reproduction just described is non-sexual; but the first and simplest form of sexual reproduction is presented by the Diatomaceæ and Desmideæ, which are very simple forms of Algæ. There is no distinction of sex, but reproduction takes place by means of the fusion into one mass of the germinal matter that forms the contents of two cells. Two individuals, each of them consisting of but a single cell, place themselves together and burst: the contents of the two mix, and from their union a fresh brood arises.[1] Although there is here no visible distinction of sex, yet what appears to be the essential condition of sexual reproduction is fulfilled; namely the fusion of the germinal matter derived from two different organisms. A similar method of reproduction is observed in Gregarinæ,[2] which are microscopic animal parasites of the simplest organisation, and probably occurs in all the simplest organisms, both vegetable and animal. The absence of sexual distinction in the lowest vegetables and animals appears to show that such distinction must have been evolved separately in the higher classes of the two kingdoms.

Simplest Form of Sexual Distinction.—In the unicellular Algæ

[1] Carpenter's *Comparative Physiology*, p. 878.

[2] Dr. Lankester in *Nature*, vol. vi. p. 484, October 10, 1872.

mentioned above, the cell-walls, after they burst and liberate their contents, are as useless and dead as the cast skin of a snake. We meet with the simplest form of the distinction between the sexes in Zygnema, an Alga of rather higher organisation, and consisting of cells united into filaments, somewhat like strung beads. Two of the filaments—that is to say, two distinct plants—approach and lay themselves alongside each other, and the contents of the cells of one filament pass over into the cells of the other, where the union is formed which is to give origin to a new brood.[1]

Purpose of Sexual Distinction.—The essential matter in sexual generation is the union of germinal matter from two distinct sources; and the primary purpose of the distinction between the sexes appears to be to increase this difference.

Universal Necessity of Bisexual Generation.—The existence of distinct reproductive organs is only a case of the "physiological division of labour;" and the process might have been universal among living beings which we actually find among many insects and other invertebrate animals, of unisexual reproduction, or parthenogenesis, in which the reproductive organs of the female act alone. But there is strong reason for believing that no organism can propagate, either in this way or by buds, for an indefinite time; and that every race will die out unless reproduced from time to time by the union of two parents.

Apparent Exceptions—Plants which do not Seed.—The evidence for the universality of this law, however, can never be complete. It must be remembered that flowers are sexual organs, and that propagation by seeds is bisexual propagation. Darwin gives a list of plants which are seldom or never known to seed, though they remain healthy, and propagate by cuttings or buds. Among these are the well-known case of the sugar-cane in the West Indies,

[1] Carpenter's *Comparative Physiology*, p 881.

and that of the common ivy in Northern Sweden and Russia.[1] These may be compared with those species of moths with which parthenogenesis (that is to say, propagation by an unfertilized female) is the rule, and the males are so few that they have never been found, though it can scarcely be doubted that they exist. But such exceptions as these are probably more apparent than real. It is probable that in the course of a time which might seem long in history, but would be very short in geology, every such species will die out if it does not obtain a new lease of life by sexual reproduction.

Hermaphrodite Animals not always Self-fertilizing. — This view of the purpose of the sexual distinction is confirmed by the facts stated by Darwin respecting the fertilization of hermaphrodite organisms. Many of these, as earth-worms and land-mollusca (snails and slugs), have the male and the female organs so placed with respect to each other that they cannot fertilize themselves, but pair, like animals with the sexes separate. And though many hermaphrodite animals do habitually fertilize themselves, yet not a single instance is known of the female organs being out of the reach of the spermatozoa of another individual occasionally entering. No terrestrial animal is known to fertilize itself, and among aquatic species the spermatozoa may be carried in currents of water.

Hindrances to Self-fertilization in Flowers.—With respect to plants, the evidence is even more remarkable. It has long been known that most flowers contain both the male and the female element, but it now has been ascertained that many flowers are prevented from fertilizing themselves, by the stamens and the pistils maturing at different times, and in other much more elaborate ways. The purpose of this is, of course, to insure something approaching to mixture of race at the production of every seed.

[1] *Variation under Domestication*, vol. ii. p. 169.

Dimorphic Flowers.—Dimorphism may be regarded as a further complication of the ordinary relation of the sexes, having obviously the same purpose, namely, to prevent too close breeding. In some dimorphic genera, though both the forms of flowers contain both male and female elements, yet each can be fertilized only by the pollen of the other.[1]

Further consideration of the subject of hybridism is postponed till we come to consider the facts of variation.

NOTE.

GROWTH OF ORGANS WITH EXERCISE.

Why do Organs Grow with Exercise? Herbert Spencer's Theory.—Woody Fibre.—It appears uncertain whether the increase in size of organs that are much exercised can be accounted for by any physical cause; or whether, like the law of habit, it is an ultimate law of life, and as such inexplicable. Herbert Spencer has made a most elaborate and ingenious attempt to prove that it is entirely due to the increased flow of blood that always takes place to and through an organ in activity.[2] He makes out an exceedingly strong argument for believing that the deposit of woody substance in the vascular tissue of plants, which is the process by which woody fibre appears to be formed, is originally due to the accelerated flow of the sap in the vessels near the surface of trunks and branches that are agitated by the wind. But it ought not to be taken for granted that the case of muscular and other animal tissue is parallel to this. In plants, the waste of the tissues is very trifling, and it is probably null in vascular tissue which is filling up and hardening into woody fibre; so that an increased flow of sap may very well fill up the vessels with the substance it brings, just as drains are silted up. But in animals, especially warm-blood animals, the waste is great and rapid; and the more any organ is exercised, the more substance it loses by waste: and it is not easy to understand why the increased flow of blood through an organ should not only increase its nutrition (which it certainly will do), but cause the nutrition to exceed the waste, so as to produce growth.

Possible Nervous Action in Increasing Nutrition in Exercised Parts.—Perhaps the excess of nutrition to which the growth is due may be in some way caused by nervous agency, which we know to be called into play by

[1] On the subject of this and the preceding paragraph, see Darwin's work on *The Fertilization of Orchids.*

[2] *Principles of Biology,* Part v. Chaps. iv., vii., and viii.

every vital action whatever among those classes of animals that have a well-developed nervous system. Such action of the nervous system would, no doubt, be inexplicable ; but it would not be more so than its action in stimulating secretion, or indeed than any strictly vital action whatever.

Increased Flow of Blood to Exercised Parts possibly due to Relaxation of the Nerves of the Arteries.—The cause of the increased flow of blood to and through parts that are in exercise does not appear to be fully understood. With respect to the muscles, I am inclined to think that Herbert Spencer has assigned an adequate cause, namely the varying pressure on the blood-vessels during muscular action. But this, obviously, will not apply to the flow of blood to the brain being greater during the waking state than during sleep, or any other flow that is directly produced by nervous action. Possibly the increased flow of blood in this class of cases may be due to the calibre of the small arteries being increased by the relaxation of the nerves that control them ; but I am not aware of any evidence tending to prove this.

CHAPTER X.

THE PROBLEM OF THE ORIGIN OF SPECIES.

HAVING considered the laws of Habit and Variation, we are in a position, not indeed to solve but to state, the question of the origin of species.

The Origin of Species is a distinct question from that of Life.—In the chapter on the Chemistry of Life,[1] we have seen that vital properties do not appear to be a resultant from the ordinary properties of matter; and that the origin of life, as well as that of matter and energy, is most probably to be referred directly to the action of Creative Power. But the origin of the distinct species and classes of living beings is a different question, and may be thus stated:—

The Theory of Evolution, i.e., *that all Species are descended from a few original Germs.*—In the chapter on Organization,[2] we have seen that organization is not the cause but the effect of life;—vitalized matter has a tendency to produce organization, just as uncrystallized but crystallizable matter has a tendency to produce crystalline form. We have also seen in the preceding chapter, that the characters of species are not absolutely invariable, but that they are susceptible of considerable change, sometimes produced, directly or indirectly, by change of external circumstances, and sometimes arising in spontaneous

[1] Chapter I. [2] Chapter IV.

variation. This fact makes the theory of Evolution at least tenable;—that is to say, the theory that all species and classes have been, not separately created, but derived by descent with modification from minute masses of protoplasm or germinal matter—perhaps from a single such mass—which was once vitalized by Creative Power.

The Arguments for Evolution are not fully stated here.—It is not the purpose of this work to state the full strength of the arguments in favour of the theory of Evolution. These are not demonstrative but cumulative; and in order to do them full justice, it would be necessary to summarize all that Darwin has said on the relation of species to each other, on Classification, Embryology and Development, Morphology, and Geographical Distribution.

I believe in Evolution, but differ from Darwin, in that I also believe in a Guiding Intelligence.—But, though I believe in the theory of Evolution to the fullest extent, I do not assent to the form of it usually and accurately called Darwin's Theory. According to Darwin, the laws of Habit and Variation, with the controlling influence of the external conditions of life, are sufficient to account for the entire process of modification whereby the most highly organized vegetables and animals have been derived from the first vitalized but unorganized germs. I altogether dissent from this:—I think the process of evolution proves the agency of an Intelligent Power, acting through and controlling the unintelligent forces of Habit and Variation, just as all the vital forces act through and control the inorganic ones. The reasons in favour of this view are to be set forth in the following chapters.

The Analogy of Individual Development is in Favour of Evolution.—There is no intrinsic improbability in the derivation of all organisms by descent from the lowest:—analogy is in its favour, and the improbability is on the other side. We

know that every individual organism, vegetable and animal alike, has been developed out of a simple germ in which the microscope shows no structure; and that there is no test of any kind whereby the germ of one organism can be distinguished from that of another, however unlike may be their mature forms. We know also that every species must have had an origin; and it is more in accordance with all probability to believe the species, like the individual, has arisen by gradual evolution, than to suppose that it suddenly started into mature life out of dust or out of nothing.

Evolution is not Contrary to Experience. Changes in Language.—It is true that the origin of the organic world by a process of evolution, is, on the whole, outside of our experience;—though, as will appear from the facts to be detailed in the next chapter, there is much more in our experience to support it than is generally believed. It is often said that any theory of the origin of species by descent from other species is contrary to experience, because all experience shows that every species produces its own kind and no other. This objection is not of much force. What is true within the limits of a very short experience is not necessarily true in a much longer time. Thus languages do not in general change perceptibly in a lifetime; but they change in historical time;—Latin has given origin to the entire group of modern Romanic languages in less than two thousand years. The outlines of continents and the heights of mountains do not sensibly change in historical time, but in geological time they are as fleeting as the outlines of a cloud. So, taking as proved that organisms are variable, nothing but indefinite time is needed for the variations to accumulate, and to become indefinitely great in total amount. The difficulty is not as to the amount of variation, but as to its receiving the direction needed.

Why the Theory of Evolution has not been earlier admitted.—It was impossible that the theory of Evolution could be enter-

tained at all, until the great antiquity of the Earth was known; for, so long as it was believed that the order of nature was only coeval with human history, it was a necessary inference that the organic creation came into existence all at once, at the beginning of things. And it was impossible that the theory could be placed on a right basis, until it was shown that the germ out of which every living thing is developed is perfectly simple and unorganized, and not, as was formerly supposed, a folded-up miniature of the perfect form.

Evolution explains Classification.—Darwin remarks that "the grand fact of the natural subordination of organic beings in groups under groups, that is to say, the fact of natural classification, which from its familiarity does not always sufficiently strike us,"[1] is explained by evolution, and in no other way. If the theory of evolution is true, the resemblance between the members of a class depends, not metaphorically but really, on kindred; genera are literally families; a perfectly accurate classification would be a genealogy; and the divergence of descent is the explanation of that divergent and redivergent form, in groups of groups, and these again grouped, which all approximately accurate classification tends to assume.

Limitations of the Principle above stated.—This, however, though generally true, must be understood with some reservations. In organic as in human genealogy, though kindred on the whole resemble each other, the degree of unlikeness between forms does not appear to have any constant relation to the length of time which has elapsed since their stocks diverged. And there are many instances of resemblance between organic forms, which do not appear to be explicable by the hypothesis of kindred;—like the strange resemblances which are sometimes observed between distant cousins.

Crystalline and Organic Species.—It has been urged against

[1] *Origin of Species*, p. 364.

the validity of the argument from classification in favour of the origin of species by descent with modification, that crystalline species also are naturally classified into groups, and into groups of groups, and yet there is no bond of descent between crystalline species. This is sufficiently answered by the fact that the unformed but formative material of organisms can only, so far as we know, be produced by organisms; but this is not true of crystals, as their formative material has a merely chemical source; so that the cases are not parallel.

Transitional Forms are often still in Existence, but mostly Lost.—An obvious objection to the theory of Evolution is, that if species have been formed by slow transition, by descent, from one form to another, we ought to find innumerable transitional forms; but instead of this, we find that each species is quite distinct.

This is partly answered by the statement that in very many cases each species is *not* quite distinct, and that we *do* find a great variety of intermediate forms; so that—what appears a strange paradox—it often happens that the more thoroughly a genus is known, the more difficult it is to determine which of its members are species and which only varieties.[1] But this answer is altogether insufficient. If species have been formed by slow transition, only a very small proportion of all the forms that must have existed are now living.

Imperfection of the Geological Record.—But why do we not find their remains entombed among the rocks?

To this objection Darwin has, I think, given a conclusive reply in his chapter on "the Imperfection of the Geological Record." On this subject it is only necessary to state his conclusions in the barest outline.

Destruction of Fossils. Denudation. Metamorphism.—Soft-bodied animals, like the naked worms and mollusca, are seldom

[1] De Candolle, quoted in Darwin's *Origin of Species*, p. 40.

preserved at all; they perish without leaving any record of their existence. The same is mostly true of land animals, though for a different reason. It is only in the rarest cases that land animals can die under such circumstances as to be buried and afterwards fossilized. As a rule, it is only the hard parts of aquatic organisms that will be fossilized and preserved; and when they are so preserved, the older the fossiliferous beds, the less will be the chance of their preservation to our age. "The stir of the forces whence issued the world"[1] is not quiet yet, and never has been quiet. The deposition of new strata never ceases; and it must be remembered that, as the quanity of matter in the world is unchangeable, if deposition is going on in one place, there must be an equivalent amount of denudation somewhere else—that is to say, an equivalent amount of destruction of old strata; though we habitually forget this, because we see the deposit and do not see the denudation.

Besides the effect of denudation in destroying old fossiliferous beds, there is the effect of metamorphism—that is to say, the effect of heat, assisted probably by the chemical agency of water and carbonic acid. It was first pointed out, I believe, by Sir John Herschel,[2] that (granting, what is unquestionable, the theory of the earth's central heat) any deposition of strata must raise the temperature of the strata underneath, exactly in the same way that putting on a thick coat raises the temperature of the skin. Such a rise of temperature, if sufficiently great, will cause a metamorphic change in the strata so covered, and will destroy their fossils. As metamorphism from this cause, as well as from the intrusion of igneous rocks, is not an exceptional but a normal action, and as the same is true of denudation, it follows that metamorphism and denudation—fire and water—are incessantly destroying the ancient records of creation; so that all that geologists can ever hope to recover are the latest leaves of the volume, and these in but a fragmentary state,

[1] Matthew Arnold.

[2] See his letter to Sir C. Lyell, in the Appendix to Babbage's Ninth Bridgewater Treatise. Darwin has made no use of this argument.

because a large proportion are covered by the sea, and others buried inaccessibly deep.

Discovery of Intermediate Forms. Reptilian Birds.—With all this, it remains true that many intermediate forms have been discovered; and, what is a most important fact, no class—no type of form—has been found among fossil species fundamentally unlike all living classes. As has been truly remarked, all fossil forms can be arranged either in or between living groups. To mention what is perhaps the most striking instance of this: till very lately, the class of Birds appeared to be isolated from all others; but recent discoveries have proved the former existence of an order connecting Birds with Reptiles.

The Arguments from Classification and from Transitional Forms support each other.—The argument in favour of Evolution from the fact of natural classification in groups subordinate to groups, and the argument from the existence of transitional forms connecting different groups, are, it is evident, arguments that point the same way and strengthen each other.

Objection, that these Prove only the Limitation of the Number of Possible Modifications.—We must here notice an attempt which has been made to show that these facts prove nothing in favour of evolution; and that they necessarily follow from the limitation of the number of possible modifications and combinations. There is, by mathematical and mechanical necessity, such a limitation in the case of many works of human art. Every bridge, for instance, is either an arched, or a suspension, or a girder bridge, or some combination of these; and no possible ingenuity will ever invent any other. Thus we find the same relations among bridges as among organisms;—a natural classification into distinct groups, with transitional forms connecting the groups;—yet it is not maintained that bridges have come into existence by descent.[1]

[1] See the article on Darwin's theory, understood to be by Professor Tait, in the *North British Review* for June 1867.

Reply;—the Number of Modifications is not Limited by any Mechanical Necessity.—This argument is one which could not have occurred to a naturalist. The reply to it is, that it assumes the facts wrongly;—the number of possible modifications among organisms is not limited as it is among bridges and other engineering works;—the limit to the number of modifications which are actually found to exist does not depend on any mechanical necessity, and is inexplicable on such a hypothesis, but is accounted for by that of Evolution. Thus among Vertebrates, the legs, when they exist, are never more than four;—among Arthropods (*e.g.*, insects, centipedes, and crabs), they are never fewer than six.[1] No mechanical necessity can be assigned for this;—there is no mechanical reason why lizards should not have run on six legs and insects on four;—but according to the theory of Evolution these are inherited family characters.

Moreover, the engineer works with the best materials that he can obtain; he builds his bridges of stone, wood, or iron, according to circumstances. No mechanical reason can be given why the Organizing Power should not do the same;—why, for, instance, no vertebrate should have a horny skeleton, and why bone is a structure which is found in no invertebrate. So far as these facts can be accounted for at all, they can be accounted for only as family characters transmitted by descent.

Full Title of Darwin's work.—The full-length title of Darwin's great work is *The Origin of Species by Means of Natural Selection; or, The Preservation of Favoured Races in the Struggle for Life.* The present is the place to give a summary of Darwin's theory, referring the reader to his work for details.

Darwin's Theory as Accounting for Improvement.—Taking the known laws of life as his data, Darwin's theory is an attempt

[1] This statement as to vertebrates needs no qualification. Among Arthropods there are a few degraded forms which have no legs, and a few species belonging to the class of true or hexapod insects which are without the fore-legs. From the evolutionist point of view such exceptions present no anomaly.

to explain the process of Evolution by purely physical causation. The theory, in outline, is simply this :—All organisms are more or less variable : no two leaves in a forest are exactly alike, and the differences are often great enough to be quite conspicuous, as in the familiar case of human faces. At the same time, these variations tend to become hereditary. Now, if any variation is such as to give its owner any advantage over other individuals of the same species, the owner of such a favourable variation will be more likely than less favoured individuals to win a place in the struggle of life, to survive, and to leave offspring. These offspring will tend to inherit the favourable variation that caused their parent to survive, and the same competition will go on among them. Those which possess the favourable variation in the highest degree will again survive, and the improvement will go on progressing and accumulating through generations. This preservation of favourable variations is what Darwin calls Natural Selection. In answer to a possible objection, it must be remarked that at Nature's feast there is not room for all; so many are born that only a fraction of the entire number can survive and leave offspring. There is therefore a struggle for existence, and the race is on the whole to the swift, and the battle to the strong.

Darwin's Theory as Accounting for Divergence.—This theory accounts not only for improvement, but also for divergence. Various kinds of favourable variations are possible, and it is improbable that they should be found together; thus, different variations will give rise to races having different characteristics. Either keen sight or keen scent, for instance, will be beneficial to a beast of prey, and because the law of probabilities makes it unlikely that variation should occur in the direction of both at once, the race which is modified in the direction of improved sight, and that which is modified in the direction of improved scent, will be different and divergent races. Thus, no doubt, have arisen the varieties of dogs that hunt in different ways. The races, however, will not diverge unless the habits which are united

with these different charaeters are sueh as to keep them apart; —otherwise their eharaeters will be eombined by interbreeding.

Summary of Darwin's Theory.—The whole of Darwin's theory, or rather the faets that eonstitute its basis, may be stated in the four following propositions:—1. All speeies are eonstantly though slightly variable, and some of these variations, by the law of probabilities, must be advantageous to their owners. 2. Advantageous variations will give their owners the best ehanee of sueeess in the struggle for existenee, and will thus be preserved by natural seleetion. 3. Any improvement, onee begun will be perpetuated by inheritanee and aeeumulated through sueeessive generations. 4. In general, many variations are possible, each of whieh is separately an improvement; and when the eireumstanees or the habits of the different varieties prevent them from interbreeding, improvement will go on in different and divergent lines.

Natural Seleetion is a Real Agent, whether All-explaining or not.—It is a question whether natural seleetion among spontaneous variations can be, as Darwin maintains, the sole agent of organie ehange and progress, and it is a question whieh I answer in the negative; I do not believe that it is the sole agent. But there ean be no doubt whatever that it is a really operative agent—a *vera eausa.* Where there are variations, some will be favourable; and where there is a favourable variation, the tendency of things will be for its possessors to have an extra ehanee of surviving in the struggle for existenee, and transmitting the variation to their descendants.

Conservative Effect of Natural Selection.—It is however to be observed that natural seleetion is capable of being a conservative as well as a progressive ageney, and is probably oftenest eonservative in its effects. It aets by destroying injurious variations as well as by preserving beneficial ones; and there are many cases where any variation from the established type

of the species is certain to be injurious. Thus, colour is, on the whole, one of the most variable characters; but if a species has acquired protective colouring—that is to say, the colour of the objects among which it lives, so as to be seen by its enemies with difficulty—any variation from this will be injurious, and will be checked by the individuals which have in any degree lost the protective colouring being seen by their enemies and destroyed. In those cases where species have lived under unchanged conditions of life through long geological ages, it is probable that they have become so well adapted to those conditions that almost any possible variation will be unfavourable, and will consequently be extinguished by natural selection. The fixity of species is much more remarkable than their variability, and is indeed so decided that until our own time it has been generally believed to be absolute. This is probably a result of natural selection; and it appears likely that natural selection, continued through ages under unchanged conditions of life, will have the effect not only of destroying injurious variations as they arise, but of greatly diminishing the tendency to variation in the entire species. Some species are exceptionally variable; and their variations, in Darwin's opinion, are neither beneficial nor injurious, and therefore have neither been fixed nor destroyed by natural selection.[1] If this explanation is true, these exceptions are of the kind which test and thereby prove the rule.[2]

Changes of Circumstances in Geological Time will Promote Organic Change.—Were the external conditions of the life of all species to remain for ever unchanged, it is possible there would be no organic progress at all, and certain that it would at the most be extremely slow. But changes in the circumstances of

[1] "I am inclined to suspect that we see, at least in some of these polymorphic genera, variations which are of no service or disservice to the species, and which consequently have not been seized on or rendered definite by natural selection." —*Origin of Species*, p. 35.

[2] *Exceptio probat regulam*, that is to say, *the exception* tests *the rule*; not *proves* the rule, as this saying is commonly mistranslated.

life must be constantly occurring throughout geological time; and, as we shall see in the following chapter, such changes promote variation. Geological, and we may add astronomical,[1] revolutions alter the climate and physical geography of entire continents; and, independently of this, geological revolutions effect vast changes in the circumstances of the life of species by either forming or removing barriers to migration. Besides —as Darwin was the first to state, with emphasis proportioned to the importance of the fact—any change in the distribution of one species is almost certain to produce changes in the conditions of the life of other species, by altering the character and abundance of their food, the character and number of their enemies, and the character of the species with which they have to compete for subsistence. It consequently appears probable that changes in specific forms are chiefly effected during, or directly after, periods of geological or climatic change. Such changes act at once directly by promoting variation, and indirectly because variations become advantageous under the changed conditions of life which previously would not have been so; and such variations are consequently selected and preserved.

Argument against Evolution from the Invariability of Minute Structure.—Dr. Beale on this Subject.—I shall conclude this chapter by noticing an important argument against the entire theory of Evolution, on the ground that though the external characters of species are variable, there is no proof that their histological, or minute structural, characters are so. Dr. Beale makes the following striking remarks on this subject:—

"The anatomical differences between corresponding tissues of closely-allied species are often so distinct that the

[1] See Mr. Croll's *Climate and Time*. I do not agree with all his results, but he has done great service to science by showing that the changes in the earth's orbit must produce climatic changes. My views on the climate of the glacial period, which differ much from his, are to be found in the *Journal of the Geological Society*, 1869 and 1876.

anatomist familiar with them could distinguish the one from the other. For example, it would be difficult to state in few words the difference between the unstriped muscular tissues of the bladder of the hyla [or tree-frog], of the common frog, and of the newt, and yet there is a recognizable difference; and corresponding differences can be demonstrated in other textures, if a comparison be carefully instituted. So also with regard to the chemical composition of the corresponding solid matters, fluids, secretions, &c., of closely-allied animals:—remarkable differences may be observed, as may be demonstrated by a careful examination of the blood, bile, or urine, for example. Such differences, affecting the minute structure and chemical composition of every part of the organism of creatures closely allied, are strong arguments in favour of the doctrine of the independent origin of distinct species; for it is scarcely reasonable to assume that any divergence in a few particulars from the general characters of the common original stock, should be accompanied by, or should necessarily involve, a change in all these points, unless such differences can be demonstrated to have occurred in the varieties of existing species; but this is a subject which has not yet been touched on by Mr. Darwin, or by those who have embraced his views."[1]

Reply;—Structure is probably Variable, but less so than Form.—Very little is yet known on this subject; nor can much be known until a systematic investigation is made with the microscope of the tissues of various species, and of various varieties of the same species, for the purpose of ascertaining the degree and the limits of their variability. My opinion, based however not on any direct evidence but altogether on analogy, is this;—that as structure differs between species and between classes, but differs less than form, so it will be found that structure varies within the limits of the same species, but varies less than form. It appears to be a general law that the minutest

[1] Beale's edition of Todd and Bowman's *Physiology*, p. 41.

structures are the least variable. Thus, the form of the leaves of any species of tree is in general tolerably constant, while the form of the entire tree is generally much more variable; and, so far as the subject is yet known, microscopic structure appears to be remarkably constant throughout the same species. Thus, a small fragment of a tooth, even in a fossil state, is often enough for the identification of a species;[1] and the same is true of shells, even when their forms are subject to considerable variation.[2]

Instance of the Pterodactyle's Bone.—The following is a remarkable instance of the constancy of minute characters:—The skeleton of a pterodactyle, which was a reptile organized for flight, has a strong resemblance in its general outline to that of a bird, but a microscopic examination of the structure of its bones shows its reptilian affinities.[3]

[1] Carpenter's *Comparative Physiology*, p. 152.

[2] My friend the Rev. John Grainger, D.D., informs me that the microscopic structure of shells presents little that is characteristic of peculiar species; but the sculpture, or external markings, often enable the species to be determined from small fragments.

[3] Carpenter's *Comparative Physiology*, p. 140.

CHAPTER XI.

THE FACTS OF VARIATION.

This Chapter is a Review of Darwin's Work on Variation under Domestication.—The chief purpose of this chapter is to review Darwin's work on *The Variation of Animals and Plants under Domestication,* and to endeavour to collect from his enormous mass of facts whatever laws we can find. If it is true that all organic species have been derived, by descent with modification, from a few minute masses of originally vitalized gelatinous matter, it is evident that we may reasonably hope to receive some light on the process of the origin of species from the laws of variation and of hereditary transmission.

Reproduction is a Modification of Growth.—The fundamental fact with which we have to do, is the law that every species reproduces its like. The physiology of vegetables and of the lowest classes of animals shows that the fact of reproduction is only a modification of the more general fact of growth. Growth and reproduction graduate into each other through the process of budding. When a bud, and the branch into which it develops, remain attached to the parent stock, the process is called growth: when they are detached, so that the bud becomes the beginning of a new plant, the process is called propagation. The inquiry into the laws of heredity and variation consequently includes the results of propagation by buds and cuttings, as well as those of sexual reproduction.

Spontaneous Variations defined as those of Unknown Origin.—Although we know something of the conditions under which organisms become variable, yet spontaneous variations are, by definition, those whereof the precise origin is unknown. The subject of the hereditary transmission of spontaneous variations is consequently doubly mysterious; including the mystery of the original variation and that of its hereditary transmission: and it will consequently be best to consider first the simpler subject of the laws of the hereditary transmission of modifications of the organism whereof the origin is known.

Mutilations are seldom inherited except when followed by Disease. Instances.—The simplest case of such modification consists in mutilation: and it is a remarkable and significant fact that mutilations are very seldom inherited. There are, however, instances of their inheritance: and Darwin sums up his conclusion on this subject in the following words:—

"On the whole, we can hardly avoid admitting that injuries and mutilations, especially when followed by disease, or perhaps exclusively when thus followed, are occasionally inherited."

He mentions as an instance that "a cow lost a horn by suppuration, and she produced three calves which had on the same side of the head, instead of a horn, a small bony lump attached merely to the skin."

The following case is no doubt a result of the same general law of life:—It has been found by Brown-Séquard that "many young guinea-pigs inherited an epileptic tendency from parents which had been subjected to a particular operation, inducing in the course of a few weeks a convulsive disease like epilepsy. This eminent physiologist bred a large number of guinea-pigs from animals that had not been operated on, and not one of them manifested this tendency."[1]

Acquisition of New Habits. Instance in Pigeons.—We know that many domestic animals acquire new habits with consider-

[1] *Variation under Domestication*, vol. ii. p. 24.

able facility; on this the possibility of teaching them depends. It is probable that the same is more generally true among wild animals than is generally believed. Darwin mentions "a curious instance of compulsion leading to changed habits. The banks of the Nile above lat. 28° 30′ are perpendicular for a long distance, so that when the river is full the pigeons cannot alight on the shore to drink, and Mr. Skirving repeatedly saw whole flocks settle on the water and drink while they floated down the stream." [1]

Modification of Habit in a Woodpecker.—Darwin elsewhere mentions a remarkable instance of modification of habit in a wild race. The *Colaptes campestris,* a species of woodpecker found in South America, in some districts "frequents trees and bores holes in the trunk for its nest;" but in other "large districts it does not climb trees, and makes its nest in holes in banks." [2]

Acclimatization. Instance in the Goose.—Acclimatization also appears, at least in some cases, to be easier than is generally believed. "According to Roulin, geese taken within a recent period to the lofty plateau of Bogota (in the Andes) at first laid seldom, and then only a few eggs; of these scarcely a fourth were hatched, and half the young birds died. In the second generation they were more fertile, and when Roulin wrote they were becoming as fertile as any geese in Europe." [3] This is the more remarkable, as the domestic goose is a singularly invariable species. It is not stated that the geese when taken to Bogota became feeble or unhealthy:—we shall see further on that a degree of change often affects the reproductive system injuriously without appearing to affect the general health at all.

Instance in Greyhounds.—Another instance of rapid accli-

[1] *Variation under Domestication,* vol. i. p. 181.
[2] *Origin of Species,* p. 142.
[3] *Variation under Domestication,* vol. ii. p. 161.

matization was that of the greyhounds which were taken to the high plateau of Mexico, and soon lost their breath when coursing in the rarefied air of that region, but their offspring suffered no inconvenience.[1] Here was acclimatization effected in a single generation, by the mere change of climate, without selection.

Hereditary Tendency of Habits. Consequent Modification of Structure.—We know that acquired habits tend to become hereditary. Thus, the habits which the pointer and the sheep-dog have acquired as the result of education, have become hereditary, and may be regarded as instincts. And when changes of habit induce structural changes, these appear generally to become hereditary. A curious instance of this is that many races of domestic animals, unlike their wild progenitors, have drooping ears; this, according to Darwin, is probably from the power of erecting them being lost through disuse, from the animals in the domestic state not having to listen for enemies or prey. "With rabbits, the drooping of the much-elongated ears has affected even the structure of the skull." [2]

Loss of the Power of Flight and consequent Changes of Structure among Birds and Insects.—Here we see that a habit, and with it a power, may be lost through disuse. Similar to this are the cases of the domestic fowl and duck, which through disuse have almost lost the use of their wings: and the bones and muscles of their wings have become smaller in proportion to the entire mass of the body than those of their wild progenitors, while those of their legs have become larger.[3] The power of flight, indeed, appears to be remarkably subject to modification and inconstant as to its presence. This is true among insects also. There are wingless genera in most of the orders of insects which are normally winged; with some beetles the presence of wings

[1] Stated on the authority of Sir Charles Lyell, in Carpenter's *Comparative Physiology*, p. 987.

[2] *Variation under Domestication*, vol. ii. p. 301.

[3] *Ibid.* vol. ii. p. 298.

is not constant even in the species; and the cultivated variety of silk-moth, though not wingless, has lost the power of flight, partly no doubt from disuse.[1]

But to return to birds: "The water-hen of Tristan d'Acunha (*Gallinula nesiotis*) can flutter a little, but obviously uses its legs and not its wings as a mode of escape. Mr. Sclater finds that the wings, sternum, and coracoids are all reduced in length, and the crest of the sternum in depth, in comparison with the same bones in the European water-hen (*G. chloropus*): on the other hand, the thigh-bones and pelvis are increased in length, the former by four lines, relatively to the same bones in the common water-hen."[2]

Ground Parrot. Dodo. Apteryx.—The kakopo or ground-parrot of New Zealand (*Strigops habroptilus*), though its wings are of full size, has almost lost the power of flight, and the keel of its sternum, which part is largely developed in flying birds for the attachment of the wing-muscles, has become rudimentary.[3] In the dodo, a gigantic bird allied to the pigeon tribe, the wings are reduced to mere stumps. These four species—the domestic fowl, the water-hen of Tristan d'Acunha, the ground-parrot, and the dodo,—belong to different orders, and are in no special way connected by kindred; yet they present a complete gradation of the stages whereby the power of the wings has been lost, and the wings themselves reduced to little more than rudiments: and all, it is impossible to doubt, from the same cause, namely the absence of any enemies that compelled them to take the wing;—for the last-mentioned three species inhabit, or inhabited, islands which were naturally free from both large and small beasts of prey.

The four species of birds just mentioned belong to orders

[1] "As moths and butterflies of all kinds reared from wild caterpillars under confinement often have crippled wings, the same cause, whatever it may be, has probably acted on silk-moths; but the disuse of their wings has, it may be suspected, likewise come into play."—*Variation under Domestication*, vol. i. p. 303.

[2] *Ibid.* vol. i. p. 287.

[3] Dr. Sclater, in *Nature*, vol. iii. p. 190.

whereof the great majority of the speeies have the power of flight. I have not mentioned the Struthious order, which differs from all other orders of birds in that none of its members can fly, though they mostly possess external wings, as the Ostrich;—and those whieh have no external wings, as the Apteryx, have rudimentary wing-bones. I believe that these also are descended from flying birds, but it is better not to raise that question at the present stage of the argument.

Impossibility of ascertaining the rate of Variation.—We may eonjecture that where the loss is eompletest the disnse has been longest; but we do not know enough to assert this with eonfidenee. It is my opinion that the time, whether stated absolutely in years or relatively to other variations, whieh is needed for any given variation to be established, is a subjeet whereon even approximate eertainty is altogether unattainable.

Monstrosities are often not Inherited. Gold Fish. Deaf-mutism.—We have next to consider the laws according to which spontaneous variations are transmitted by deseent. The only law on this subjeet whieh appears to be established with any degree of eertainty, is that the more suddenly variations arise, the less eertainty there is of their being inherited: and this is not by any means a eonstant law, but only an average tendeney. Thus, monstrosities are very eommon among gold-fish, a speeies which is not known to oeeur in a state of nature, and has been kept for centuries in confinement under unnatural eonditions. "Some of these monstrosities are not inherited; for Sir R. Heron kept many of these fishes, and placed all the deformed fishes, namely, those without dorsal fins and those with a double anal fin or a triple tail, in a pond by themselves; but they did not produce a greater proportion of deformed offspring than the perfeet fishes." [1] It is perhaps a faet of the same elass that total deafness—deaf-mutism—is seldom inherited.[2]

[1] *Variation under Domestication*, vol. i. p. 296.
[2] *Ibid.* vol. ii. p. 22.

Heredity of Albinoism and Colour-blindness.—On the other hand, albinoism, which is certainly a somewhat monstrous character, is generally hereditary, and colour-blindness is frequently so.[1] This, however, may be in some degree explained by Darwin's significant remark already quoted, that mutilations are inherited only when accompanied by disease, that is to say by functional disturbance: the hereditary tendency of many diseases is well known, and albinoism and colour-blindness are diseases, or at least functional rather than structural peculiarities.

Summary on Heredity. Partially monstrous characters sometimes become hereditary.—We can conclude on this subject only that all characters tend to be inherited, without any exceptions in the case of those which have arisen gradually, through successive generations, and have thus become characters of a race; but with some scarcely intelligible exceptions in the case of monstrosities and morbid variations. Sudden variations of form, however, even when of somewhat monstrous character, are sometimes strictly inherited; and we shall see farther on that races, scarcely distinguishable from species, have thus arisen under domestication.

Problem of the Cause of Variation. It appears to be a Law of Life.—But the first question that occurs to us respecting spontaneous variations, is why they occur at all;—why the offspring is not exactly like its parent. The most obvious reply to this would be, that variation is due to differences in the external conditions of life,—climate or food for instance,—acting on the parents. But were this so, twins ought to be exactly alike; and yet they differ as do the other children of the same parents, though generally somewhat less. Moreover, as Darwin has remarked, the not uncommon fact of one bud on a tree varying from the character of the stock, while the rest of the tree remains unchanged, shows how independent variation may be of external circumstances.

[1] *Variation under Domestication*, vol. ii. p. 9.

Darwin has shown strong reasons for believing that variability is a universal law of life;—that absolute fixity of character does not exist;—and that no two individuals, however nearly akin, are perfectly alike. Some races are however more variable than others, and the tendency to variation is itself variable, both as between different races and different parts of the organism. General diffused variability of the entire organism has the chief effect in making possible the formation of improved races by artificial selection. Growers who make a business of obtaining new kinds of plants from seed, find that it is better for a variety to vary in the opposite direction to that required than not to vary at all: and that a good variety is generally the precursor of a better one.

Stimulants to Variation. Excess of Food, Change of Conditions, Mixture of Race.—According to Darwin, there are three great stimulants to variation:—excess of food, change of the conditions of life, and mixture of races. It is necessary to mention these here:—we shall speak of them more in detail further on.

Reversion.—Variation has always to contend against the tendency to reversion, that is to say the reappearance of ancestral characters. In variable races there are three conflicting tendencies; namely, heredity, or the tendency of organisms to resemble their parents: variability, or their tendency to differ from their parents: and reversion, or their tendency to resemble, not their immediate parents, but the ancestors from which those parents have varied. Where there is much general variability, some of the variations usually run in the direction of reversion: and whatever gives an impulse to variability gives an impulse to reversion also. Thus, among all the breeds of the pigeon, which has varied more wonderfully under domestication than any other animal species, individuals, according to Darwin, are occasionally found which have reverted to the slaty blue colour and the bar on the wing which distinguish the original

race: and any mixture of the breed promotes variation, and also increases the number of instances of such reversion.[1]

Variation is held in check by Reversion.—The tendency to indefinitely great variation is held in check by the tendency to reversion. For this reason the amount of divergence from the original stock which can be obtained by those who rear and select animals and plants, is not that which would be obtainable if variations in the desired direction could be added together indefinitely, but only that which is due to the excess of the tendency to fresh variation over the tendency to reversion. Darwin says of domestic races:—"From the tendency to reversion and to continued variability, those parts which are now undergoing rapid improvement through selection are likewise found to vary much. Consequently high-bred animals when neglected soon degenerate."[2] Either the total amount of variation which is possible is an intrinsically limited quantity; or, what comes to the same result, the tendency to reversion increases with the increasing divergence of the race from its original stock, until at last further variation ceases.

Pedigree Wheat.—The history of the so-called "pedigree wheat" is an excellent instance of this law. The cultivator who has obtained that variety has arrived at the following conclusions:—[3]

"Where room has been afforded to the plant for its natural development,[4] every fully developed plant, whether of wheat, oats, or barley, presents an ear superior in productive power to any of the rest on that plant.

"Every such plant contains one grain which, upon trial, proves more productive than any other.

[1] *Variation under Domestication*, vol. ii. pp. 29, 48. [2] *Ibid.* vol. ii. p. 248.

[3] "On the Law of the Development of Cereals," by F. F. Hallett, F.L.S., in the *British Association Transactions*, 1869, p. 113.

[4] This, I suppose, means that the ground must be kept clear of weeds, and the plants not crowded together;—a condition which in the wild state can occur but seldom.

"The best grain in a given plant is contained in its best ear.

"The superior vigour of this grain is transmissible in different degrees to its progeny.

"By repeated careful selection the superiority is accumulated.

"The improvement, which is at first rapid, gradually after a long series of years is diminished in amount, and eventually so far arrested that practically a limit to improvement in the desired quality is reached.

"By still continuing to select, the improvement is maintained, and practically a fixed type is the result."

Small Dogs.—We see that in this case, variation has in the course of a few years reached its limit. A similar instance has been pointed out in the case of dogs.[1] It appears impossible to obtain a smaller dog than the smallest that has been bred up to the present time. Very small dogs are so prized as to have a considerable money value, and we may fairly infer that smaller ones than the smallest would be bred by mating the smallest that are now to be found and selecting the smallest of the offspring, were it not found impossible to obtain any such result, in consequence of variation having reached its limit. I do not know in what way the limit is reached, whether smaller dogs than the smallest are not born, or die early when they are born:—in either case the result is the same for practical purposes, and not very different for the purpose of biological theory.

The tendency to Reversion probably wears out with time.—Must we then go back to the old doctrine that variation is absolutely limited, and species unchangeable? I do not think this follows. Nature has not only historical but geological time wherein to work;—and it is probable that the tendency to reversion, whereby the tendency to further variation is counteracted, is capable of wearing out by mere lapse of time, so that the

[1] See the article on Darwin's theory in the *North British Review*, June 1867, understood to be by Prof. Tait.

character of the new variety will become a starting-point for fresh variation. Direct proof of this does not appear to be forthcoming, but such a hypothesis is consistent with all that we know of the laws of habit.[1] It must however be admitted that we can scarcely ever be certain that the tendency to reversion has altogether disappeared. Darwin suggests that the occasional appearance of a sixth finger in man may be due to reversion to the character of an ancestor very far down in the vertebrate scale. This however is possible only in the case of reversion to the original race from which the derived race has been modified. Reversion also often occurs to the character of a single ancestor with which the breed may have been crossed, but though this tendency sometimes lasts through many generations, it does not continue for an indefinite time.

Reversion in Mixed Races. Pigeons and Sheep.—Reversion in a mixed race takes the form of a tendency to assume the character of the original stock from which both the immediate parents are descended. Darwin says:—"When two varieties are crossed, both of which differ in colour from their parent stock, there is a strong tendency in the young to revert to the aboriginal colour."[2] When two very unlike races are mixed, such as two very different breeds of pigeons, the offspring are generally so variable, and the tendency to reversion is so strong, that it is difficult, even by careful selection, to obtain a permanent breed of exactly intermediate character; and a great increase is given to the tendency, which is not extinct in any race of pigeons, to revert to the original type of the species, with its slaty blue colour and bars on the wings.[3] Blackness in sheep, also, is beyond doubt a reversion to the character of the original wild race. When ancestral characters like these get back into a race, they have a much stronger tendency to perpetuate themselves than merely accidental variations.[4]

[1] See the chapter on that subject (Chapter IX).
[2] *Variation under Domestication*, vol. i. p. 110.
[3] *Ibid.* vol. i. p. 201.
[4] *Ibid.* vol. i. p. 201.

I will mention some other examples of the same law.

Horses.—"There is a latent tendency in all horses to be dun-coloured and striped; and when a horse of this kind is crossed with one of any other colour, it is said that the offspring are almost sure to be striped." [1]

Striped Flowers.—Striped flowers, like variegated leaves, are in most cases a mere "sport;" so that, though they can be propagated truly by seed, they have a tendency to revert to the original uniform colour; and "when once crossed by a uniformly coloured variety, they ever afterwards fail to produce striped seedlings." [2]

Rabbits.—The silver-grey rabbit is a variety which "breeds true" when kept apart, but if a warren is stocked with both the silver-grey and the common kinds, in a few years the entire race will have gone back to the common kind.[3]

Reversion is rare in the Hybrids of Wild Plants. It probably depends on Variability.—It is remarkable that reversion seldom occurs in hybrid plants raised from wild races, though it is common when the parents have been cultivated. Max Wichura, who experimented on the hybridization of willows in the wild state, never saw an instance of reversion.[4] As cultivated races are more variable than wild ones, this appears to show, what is intrinsically probable, that the tendency to reversion increases with variability, and in some degree depends on it.

Complexity of the Facts of Reversion. Peloria.—The facts of reversion are necessarily complex, because reversion may be either to an immediate ancestor or to a remote one. There is a most interesting instance of this in what is called "peloria' in flowers. We have every reason to think that the original

[1] *Variation under Domestication*, vol. ii. p. 69.
[2] *Ibid.* vol. ii. p. 70.
[3] *Ibid.* vol. i. p. 112.
[4] *Ibid.* vol. ii. p. [illegible]

form of flowers was what is called, though not very accurately, "regular;" that is to say with all the segments alike, so as to approach in form to a circle or a regular polygon. Many orders, however, by the unequal development of their segments, and especially of the petals, have become what is called "irregular," though "bilateral" would be a more accurate expression. Peloria consists in the production of regular flowers by a normally irregular species, and is no doubt a reversion to the original form of all flowers. Not only individual flowers may become peloric, but there are peloric varieties capable of propagation, and when any cause occurs to promote variation, such as change of soil or crossing the breed, such varieties have a tendency to revert to the regular form of the species. Darwin crossed peloric snapdragon with pollen of the common form, and common snapdragon with pollen of the peloric form, raising two great beds of seedlings, whereof not one was peloric: though the peloric variety propagates truly when fertilised with its own pollen.[1] Here is a double tendency to reversion:—the snapdragon in becoming peloric reverts to the ancestral character of all flowers; and then in ceasing to be peloric and again becoming irregular, it reverts to that of its more immediate ancestor in the species, which is also the character of the order (Scrophulariaceæ) to which the snapdragon (*Antirrhinum*) belongs.

The Converse of Peloria does not occur.—It is an important fact that the converse of peloria does not occur: that is to say, we never find a normally regular species producing irregular varieties;[2] though it is true that we do find irregular species and genera in normally regular orders. This absence of tendency in regular species to vary in the direction of irregularity

[1] *Variation under Domestication*, vol. ii. p. 70.

[2] *Ibid.* vol. ii. p. 58. Darwin infers from this, that "pelorism is not due to chance variability, but to either arrest of development or reversion." May not arrest of development constitute reversion? If, as appears to be often the case, the young or undeveloped form resembles the ancestral, a specimen whereof the development has been arrested will show a reversion to the ancestral form.

strongly supports the opinion that the earliest flowers, from which the present orders are descended, were all regular.

Probable Cause of Irregularity in Flowers.—But here arises a difficulty. If all the characters of species have arisen from variations that occurred in their ancestors, flowers from being regular must have become irregular by variation: and as the irregular form is found in many tribes which are in no special degree akin, it must have appeared not once but often during the evolution of the flower-world. Why then do not regular flowers at the present day present irregular variations?

It seems very probable that irregularity in flowers is not due to spontaneous variations, but is a functionally produced modification, chiefly due to the position of the flowers with respect to the stem and to each other, causing them to be most developed on the side towards the light.[1] This hypothesis is supported by the fact that "in our greenhouse Pelargoniums, the central flower of the truss is often peloric,"[2] and the central flower is of course that whereof the exposure to light and air is most nearly alike all round.

Before we go on to the more complex questions of variation, let us return to the subject of its causes. We have stated[3] the chief of these to be excess of food, change of the conditions of life, and mixture of races.

Excess of Food inducing Variability in Cultivated Races.—The first of these three is perhaps the chief cause of the great variability of most domesticated races, both animal and vegetable, when compared with their wild stocks. Cultivated plants, even though under otherwise natural conditions and not manured, obtain more nourishment than they would be able to obtain in the wild state, from the destruction of weeds, and, in the more

[1] See Herbert Spencer's *Principles of Biology* on this subject.
[2] *Variation under Domestication*, vol. ii. p. 167.
[3] See p. 134.

careful kinds of cultivation, the assignment of a distinct portion of soil to each plant. Manure, which is simply concentrated and abundant nourishment, is a great stimulus to variation, so that when nurserymen desire to keep the character of a bed of seedling plants uniform, they grow them without manure.

Variability induced by Changed Conditions of Life. Confinement, Cultivation, Grafting.—The next cause of variability that we have mentioned, is change of the conditions of life. This is of course influential with domestic races of both animals and plants, for the change from the wild to the domestic state must generally be great: but the effect of this and of the last mentioned cause must be often impossible to separate, so as to show how much is due to each. There are cases, however, where variation appears to be exclusively due to change, and very slight change, of conditions. "Azara has remarked with much surprise, that while the wild horses on the Pampas are always of one of three colours, and the cattle always of a uniform colour, yet these animals when bred on the uninclosed *estancias* (or cattle-farms), though kept in a state which can hardly be called domesticated, and apparently exposed to almost identically the same conditions, nevertheless display a great variety of colour. So, again, in India several species of freshwater fish are only so far treated artificially, that they are reared in great tanks; but this small change is sufficient to induce much variability."[1] Darwin remarks also that "whether or not cultivated plants have received nutriment in excess, all have been exposed to changes of various kinds. The seeds of culinary and agricultural plants are carried from place to place." He states elsewhere that "nearly all the plants which cannot be propagated with any approach to certainty by seed, are kinds which have long been propagated by buds, cuttings, tubers, &c., and have in consequence been frequently exposed during their individual lives [that is to say, during the intervals between propagation by seed] to widely diversified conditions of life.

[1] *Variation under Domestication*, vol. ii. p. 250.

Plants thus propagated become so variable that they are subject even to bud-variation." [1] And further: certain fruit-trees truly propagate their kind while growing on their own roots, but when grafted on other stocks they produce seedlings which vary greatly.[2] It is obvious that grafting is an important change in the conditions of the life of the grafted plant.

Change of Climate and of Food are not important Causes of Variation.—On the subject of stimuli to variation, Darwin makes the following remarks, which are certainly surprising:—

"It does not appear that a change of climate, whether more or less severe, is one of the most potent causes of variability; for in regard to plants Alphonse de Candolle, in his *Geographie Botanique,* repeatedly shows that the native country of a plant, where in most cases it has been the longest cultivated, is that where it has yielded the greatest number of varieties."

"It is doubtful whether a change in the nature of the food is a potent cause of variability. Scarcely any domesticated animal has varied more than the pigeon or the fowl, but their food, especially that of highly-bred pigeons, is generally the same." [3]

Change of conditions does not act on all races alike in producing variation. The goose, for instance, has produced very few varieties,[4] and we may say the same of the ass, though in some countries the breed has been much improved by selection.[5]

It sometimes requires time for these stimulants to variation to produce their effect. "When plants are first subjected to culture, it has been found that during several generations they do not vary." [6] On the other hand, when a species has been transplanted to new conditions of life, it is sometimes variable at first, and becomes less so when habituated to its new conditions. Thus, some varieties of wheat are mentioned which

[1] *Variation under Domestication*, vol. ii. p. 26.
[2] *Ibid.* vol. ii. p. 26.
[3] *Ibid.* vol. ii. pp. 256-7.
[4] *Ibid.* vol. i. p. 287.
[5] *Ibid.* vol. ii. p. 236.
[6] *Ibid.* vol. ii. p. 64.

when introduced from Spain into Germany, were variable for the first few years, but afterwards became more constant.[1]

The third great cause of variation is mixture of race.

Gradation between Perfect Mutual Fertility and Sterility effected in different ways.—It is only slight mixtures of race that are possible: when the difference is great, there is no offspring. But between perfect mutual fertility, as between members of the same race, and total mutual sterility, as between members of very unlike races, there is an indefinite number of gradations.

"The sterility of distinct species when first united, and that of their hybrid offspring, graduates from zero, where the ovule is never impregnated and a seed-capsule never formed, up to complete fertility."[2] What is very remarkable, the gradation is effected in various ways. "The degree of sterility of a first cross between two species does not always run parallel with those of their hybrid offspring. Many cases are known which can be crossed with ease, but yield hybrids excessively sterile, and conversely, some which can be crossed with great difficulty, but produce fairly fertile hybrids."[3] Sometimes, as in the well-known case of the horse and the ass, the two parent species breed quite freely together, and the offspring is vigorous, but it is barren. Sometimes, as Max Wichura found to be the case with willows, the hybrids are "generally tender in constitution, dwarf, and short-lived."[4] Sometimes, and this is very common among plants, when a flower is fertilized with the pollen of a different species, seed is produced, but inferior in quantity or quality. Darwin mentions a remarkable case of this last, where, nevertheless, a mixed race was formed. Two very distinct varieties of maize, one tall and with red seeds, the other dwarf and with yellow seeds, had grown side by side for years without hybridizing, which they would have been certain to do had they been perfectly fertile together: when they were

[1] *Variation under Domestication*, vol. i. p. 315.
[2] *Ibid.* vol. ii. p. 179.
[3] *Ibid.* vol. ii. p. 179.
[4] *Ibid.* vol. ii. p. 131.

artificially hybridized, only one head out of twenty-two produced good seeds, and those numbered but five; yet "the hybrid plants raised from the five seeds were intermediate in structure, extremely variable, and perfectly fertile."[1]

The Mutual Infertility of unlike Species perhaps depends on Lapse of Time since the Races diverged.—We do not know on what the mutual infertility of unlike species depends. It is certainly not on mere visible unlikeness; for the horse and the ass, which do not produce fertile offspring, have far more apparent resemblance to each other than have the various varieties of domestic dogs and pigeons, which are perfectly fertile together. Nor, what is much more surprising, does it depend "on ordinary constitutional differences: for annual and perennial plants, deciduous and evergreen trees, plants flowering at different seasons, inhabiting different stations, and naturally living under the most opposite climates, may often be crossed with ease."[2] Mutual infertility may, perhaps, depend merely on the time which has elapsed since the stocks diverged. This in the case of wild races is generally to be measured not by historical but by geological periods; so that I offer this suggestion only as a conjecture, which there are no means of verifying, though I think it probable.

Beneficial Effects of Crossing the Breed.—The offspring of different varieties of the same species are, according to Darwin, generally well-grown, vigorous, and hardy: and the same is generally true of hybrids, that is to say the offspring of distinct but allied species. It must not be forgotten, however, that the distinction between varieties and species is now found not to be absolute, but to admit of gradation: and the law which was formerly believed to afford a perfect criterion—namely, that varieties are mutually fertile, while species are not so—though generally true, proves to admit of exceptions. The truth appears

[1] *Variation under Domestication*, vol. ii. p. 105.
[2] *Ibid.* vol. ii. p. 179.

to be, that a certain moderate degree of distinctness of race is best for the offspring: when the individuals mated are too nearly akin, the offspring are deficient in vigour: when they are too distinct in race, there is no offspring.

Hybrids are Barren though Healthy.—The most remarkable secondary law on this subject is, that with increasing difference of race between the parents, the reproductive system of the offspring is generally affected first. Thus, the mule is barren, though as strong and healthy as either of its parents.

Barrenness caused in Animals by Captivity; in Plants by change of Climate.—This is probably connected with the fact that when animals are kept in captivity, and consequently under more or less unnatural conditions, they frequently become barren, though otherwise not injuriously affected. It is well known that the elephant, though eminently tameable, will not breed in captivity; the same is true of hawks and parrots, though they also are easily tamed; and, what is much more surprising, the same is true of the partridge, though it belongs to the same order with the pheasant and the domestic fowl.[1] Indeed, according to Darwin, it is rather the exception than the rule when any animal breeds freely in captivity. We see something similar among cultivated plants; thus, "the Persian and Chinese lilacs, though perfectly hardy, never here produce a seed."[2] In these cases, the change that causes sterility appears to be change of climate.

Exceptions among Animals.—But to return to the subject of animals;—the exceptions to the rule of animals not breeding in captivity are quite unaccountable. The ferret breeds freely, but allied species not at all; and no squirrel is known to do so with the exception of the flying squirrel.[3]

[1] *Variation under Domestication*, vol. ii. p. 156.
[2] *Ibid.* vol. ii. p. 164
[3] *Ibid.* vol. ii. pp. 151–2.

Sensitiveness of young and embryonic organisms.—Even "when conception takes place under confinement, the young are often born dead, or die soon, or are ill formed."[1] This appears to be a case of the general law, that young and embryonic organisms are more sensitive than mature ones to injurious influences—perhaps we may say to external influences of all kinds. It is a well-known instance of the same law, that European children are extremely difficult to rear in tropical climates, even in localities where their parents are able to remain healthy.

Connexion of variability with susceptibility of the reproductive system.—Darwin remarks that there must be a close connexion between "the remarkable susceptibility of the reproductive system to changes in the conditions of life,—a susceptibility not common to any other organ,"[2] and the variability of the offspring produced under such conditions when fertility has not been destroyed.

Hybridization of Flowers.—The subject of hybridization is studied with comparative facility in flowering plants:—fertilization being artificially effected by placing the pollen of one flower with a camel's-hair pencil on the stigma of another. When pollen from different flowers is laid on the same stigma, either in this way, or by the visits of insects, which are the means which nature appears to have generally provided for the fertilization of the larger and more conspicuous flowers, the pollen of a species which is too remote to have any of that affinity whereon hybridization depends, produces no more effect than so much inorganic dust.

Antagonism between Growth and Reproduction.—Hybrids are generally though not always remarkable for strength and vigour, and occasionally for fertility also: but the maxima of vigour and of fertility do not necessarily coincide: as is shown by the

[1] *Variation under Domestication*, vol. ii. p. 158.
[2] *Ibid.* vol. ii. p. 177.

well-known fact that the excision of the reproductive organs in early life tends to promote growth. There appears indeed to be a very general antagonism between growth and reproduction. "Many of the best fruits are nearly or quite sterile." "Plants which grow too luxuriantly sometimes do not flower, or, if they flower, do not seed. To make European vegetables under the hot climate of India yield seed, it is necessary to check their growth."[1] It belongs to the same general law, that propagation by seed and propagation by buds and suckers tend to exclude each other. We know that hybrids tend to be sexually barren; and "all experimentalists have remarked on the strong tendency in hybrids to increase by roots, runners, and suckers."[2] It appears possible for either luxuriance or sterility to be the cause of the other. But there is no constant connexion, either inverse or direct, between these two characters;—a slight mixture of race generally promotes both fertility and growth.

Darwin's experiments on the Fertilization of Flowers.—It is probable that in the great majority of cases the maximum reproductive effect—that is to say the most numerous and prolific seeds—are produced by the pollen of another plant of slightly different race; but Darwin details experiments which show the benefit of pollen from another plant, even when there is no appreciable difference of variety or of the circumstances of growth. He says: "The plan which I have followed in my experiments is to grow plants in the same pot, or in pots of the same size, or close together in the open ground: to carefully exclude insects: and then to fertilise some of the flowers with pollen from the same flower, and others on the same plant with pollen from a distinct but adjoining plant. In many but not all of these experiments, the crossed plants yielded much more seed than the self-fertilized plants."[3] It was found that the plants from the crossed seed were stronger than the others, and more fertile. The experiments were

[1] *Variation under Domestication*, vol. ii. p. 168.
[2] *Ibid.* vol. ii. p. 172. [3] *Ibid.* vol. ii. p. 127.

continued through two generations more, with the same result: and in some cases the difference was astonishingly great between the vigour of the seedlings from the flowers fertilized with their own pollen, and those fertilized with pollen from plants growing beside them.

Dependence of the benefit of Crossing on difference of conditions.—Darwin elsewhere says:—"The mere act of crossing by itself does no good. The good depends on the individuals which are crossed differing slightly in constitution, owing to their progenitors having been subjected during several generations to slightly different conditions, or to what we call in our ignorance spontaneous variation."[1]

Exceptions to the law of benefit by Crossing.—It might be supposed that the law of benefit by slightly crossing the breed would be free from exceptions; but such is not the case. We have seen[2] that there are many plants which are propagated for an indefinite time without ever seeding, and consequently without any possibility of a cross; and Darwin mentions instances where self-fertilization appears to be better than cross-fertilization. He states that "varieties sometimes appear which, when self-fertilized, yield more seed and produce offspring growing taller than their self-fertilized parents, or than the intercrossed plants of the corresponding generation."[3] This is stated specially of *Ipomœa* and *Mimulus;*[4] and Darwin remarks that "the appearance of such varieties bears on the existence under nature of plants which regularly fertilize themselves, such as the *Ophrys apifera* (usually known as the Bee Orchis) and a few other orchids."[5]

Case where a plant's pollen and stigma are mutually poisonous.—Almost all flowers can be fertilized with their own pollen. But Fritz Müller, the same eminent naturalist who has

[1] *Cross and Self-fertilization*, p. 27. [2] See p. 109.
[3] *Cross and Self-fertilization*, p. 348. [4] *Ibid.* p. 351. [5] *Ibid.* p. 350.

contributed so much to our knowledge of the structure and metamorphoses of the Crustacea, has made the remarkable discovery that the flowers of several species of *Oncidium*, an Orchidaceous genus which he has studied in the wild state in Brazil, cannot be fertilized with the pollen of their own flowers, though they can be fertilized with ease with that of another plant of the same species, and in some cases with that from flowers of different genera. In some species of this and allied genera, the same observer has found that a flower's own pollen and the stigma act on each other like poison:—"the surface of the stigma in contact with the pollen, and the pollen itself, becoming in from three to five days dark brown, and then decaying."[1] Darwin remarks on this:—"It is interesting to observe the graduated series from plants which, when fertilized by their own pollen, yield the full number of seeds, but with the seedlings a little dwarfed in stature, to plants which when self-fertilized yield few seeds: to those which yield none: and lastly to those in which the plant's own pollen and stigma act on each other like poison."[2]

Power of Self-fertilization lost but restored by Grafting.—We expect to find everything that is strange among the Orchidaceæ, but a fact almost as strange has been found in the very different genus *Passiflora*, or passion-flower. In this genus "it has long been known that several species do not produce fruit unless fertilized by pollen taken from distinct species."[3] This however is probably due to unnatural conditions under cultivation: and it is most remarkable that a plant of *Passiflora alata* has become self-fertilizing in consequence of being grafted on a plant of a different species of the same genus.[4] This, as Darwin remarks, "shows how small a change is sufficient to act powerfully on the reproductive system."[5]

Loss of Fertility between Animals of too near kindred.—Similar instances occur in the animal kingdom. "With pigs,

[1] *Variation under Domestication*, vol. ii. p. 134. [2] *Ibid.* vol. ii. p. 141.
[3] *Ibid.* vol. ii. p. 137. [4] *Ibid.* vol. ii. p. 138. [5] *Ibid.* vol. ii. p. 141.

first-rate animals have been produced after long-continued close interbreeding, though they had become extremely infertile when paired with their near relations. The loss of fertility, when it occurs, seems never to be absolute, but only relative to animals of the same blood." [1]

Summary.—We thus see that in general, though with a few exceptions, the maximum of mutual fertility, and of vigour in the offspring, occurs when there is a slight mixture of race. When there is no mixture of race, as when animals are constantly bred in-and-in, and when flowers are fertilized with their own pollen, there is a tendency for the race to lose vigour and fertility, until at last barrenness can be prevented only by mating with a distinct race. When on the contrary the races mated are too distinct, there is a tendency to mutual infertility. Sometimes the offspring are barren, as in the case of the mule; sometimes they are few in number, as in many cases of the fertilization of plants with the pollen of distinct species. Sometimes they are small, feeble and sickly, as Max Wichura found to be the case with hybrid willows; and when the distinctness of race is great, the mutual infertility is complete.

Connexion between variability and facility of Hybridization. Domestic races of Animals.—It seems possible that facility of hybridization may to some extent depend on variability. Max Wichura's willows were of uncultivated varieties, and, as such, less variable than cultivated varieties generally are; and perhaps their difficulty of hybridization was connected with their want of variability. I do not, however, know of any evidence that tends to prove such a connexion, unless the opinion is true which Darwin has adopted from Pallas, that long-continued domestication tends to render mutually fertile distinct though nearly allied species, which are mutually sterile in the wild state; for, as we have seen, it is certain that domestication promotes variability. The facts he quotes seem to me, however, to

[1] *Variation under Domestication*, vol. ii. p. 143.

prove only, what is quite different, that domestication tends to overcome the repugnance which animals naturally manifest against associating with a different race from their own. This repugnance shows itself even when there is no distinction of species, as in the case of highland and lowland cattle: and in such cases it is probably no more physiological than the disposition of Europeans in Asia or Africa to associate with each other rather than with natives of the country.

Mixture of races in domestic species.—It appears, however, to be tolerably certain that some domestic species, among which are the dog, the pig, and the cow, are of mixed race, being descended from two or more wild species. But the pigeon, which is the most wonderfully variable of them all, is descended from but a single wild species, the common rock-pigeon, *Columba livia.*

Prepotency in impressing character on the offspring. Reversion.—When two individuals not very unlike each other are mated, the offspring are generally of an intermediate character; but in some cases one parent is prepotent over the other, and impresses its likeness more strongly than the other on the offspring. Sometimes the prepotency runs more in one sex than in the other: thus the ass is prepotent over the horse, and "the prepotency runs more strongly through the male than through the female ass: so that the mule resembles the ass more closely than does the hinny."[1] It does not appear that prepotency follows any ascertainable law, except that, as we have seen while on the subject of reversion, a parent that resembles the original stock of the race is generally prepotent over a much modified parent, and causes the offspring to revert.[2]

Difficulty of forming a permanent race of intermediate character.—It is found among pigeons and other domestic

[1] *Variation under Domestication*, vol. ii. p. 67.
[2] See pp. 137, 138.

species which can be easily crossed, that when two very distinct races are mated, the offspring for the first generation are of intermediate character; but afterwards they become so variable that a permanent race of intermediate character is very difficult to obtain. It thus appears—contrary, I think, to what might have been expected—that the tendency to variation which is produced by the crossing of unlike races, does not attain its maximum for the first few generations. This may be compared with the fact that when plants are first brought under cultivation, it sometimes takes some years before the increased variability due to cultivation attains its maximum.[1] But, to return to the subject of domestic animals:—"In the course of time and by the aid of selection and careful weeding, it is practicable to establish a new breed. After six or seven generations the hoped-for result will in most cases be obtained, but even then an occasional reversion, or failure to breed true, may be expected."[2]

The "Himalayan Rabbit."—There are, however, some instances of very mixed races "breeding true" from the first. These are not always of exactly or nearly intermediate character, but have sometimes assumed a character of their own from the first. Such a race ought perhaps to be regarded not as a crossed breed, but as an independent variety originating in a cross. The so-called Himalayan rabbit is one of the most remarkable instances of the kind: but this case is complicated by the race being albino, which is a somewhat monstrous character. This breed "was formed by crossing two varieties of the silver-grey rabbit, although it suddenly assumed its present character, which differs much from either parent breed, yet it has ever since been easily and truly propagated."[3]

Incapacity of some races to form a crossed breed, even when mutually fertile.—There are many cases where breeds are quite

[1] See p. 142.
[2] *Variation under Domestication*, vol. ii. pp. 96, 97.
[3] *Ibid.* vol. i. p. 108; vol. ii. p. 97.

fertile together, and yet show a difficulty in mixing. One of the most decided instances of this on record is that of the otter sheep, a somewhat monstrous breed which arose in North America about the beginning of the present century. It suddenly originated with a single lamb: and when the common and the otter sheep bred together, the lambs were of either the common or the otter kind, but never of mixed character.[1] Many such instances are described, of the incapacity of races for mixing so as to form a crossed breed, even when they are mutually fertile. When a black and a white game-fowl are mated, the offspring "are of both breeds of the clearest colour."[2] "Sir R. Heron crossed during many years white, brown, black, and fawn-coloured Angora rabbits, and never once got these colours together in the same animal, but often all four colours in the same litter."[3] There is an approach to this when some of the children of the same parents resemble the father and some the mother.

This seems to depend on a variety having arisen suddenly.—Darwin states that "when any character has suddenly appeared in a race as the result of a single act of variation, as is general with monstrosities, and this race is crossed with another not thus characterised, the characters in question do not commonly appear in a blended condition in the young, but are transmitted to them either perfectly developed or not at all."[4] This principle is important as regarding the inheritance of monstrosities, though it probably applies to many variations which are in no degree monstrous; and it seems likely that those varieties which are unable to combine with the parent-stock of the species are always such as have arisen suddenly.

Segregation, in the individual offspring, of characters derived from the two parents.—Sometimes this tendency to the segregation of the elements derived from the two parents is shown in a

[1] *Variation under Domestication*, vol. i. p. 100. [2] *Ibid.* vol. ii. p. 92.
[3] *Ibid.* vol. ii. p. 92. [4] Darwin's *Descent of Man*, vol. i. p. 223.

more curious way by their affecting different parts of the individual organism of the mixed offspring. "According to Rengger, the hairless condition of the Paraguay dog is either perfectly or not at all transmitted to its mongrel offspring: but I have seen one partial exception in a dog of this parentage which had part of its skin hairy and part naked, the parts being distinctly separated as in a piebald animal. When Dorking fowls with five toes are crossed with other breeds, the chickens often have five toes on one foot and four on the other. Some crossed pigs raised by Sir R. Heron between the solid-hoofed and the common pig had not all the feet in an intermediate condition, but two feet were furnished with divided and two with united hoofs." [1]

Bud-variation.—Before we go any further, it is necessary to consider the very curious subjects of bud-variation and graft-hybridism.

In one sense, as we have seen, every new individual continues the life of its parents: in another sense, every bud that is capable of living when separated is a new individual: and the two cases of mere budding and true bisexual generation graduate into each other. The life of the new individual is most distinct when it is the result of bisexual generation, and least so at the opposite extremity of the scale: and the tendency to variation seems to depend on the distinctness of the new life: it is greater in plants raised from seed than in those raised from buds, and greater with buds taken from the root than from the stem. Darwin says on this subject:—"Many varieties, whether originally produced from seeds or buds, can be securely propagated by buds, but generally or invariably revert [when propagated] by seed. So also, hybridized plants can be multiplied to any extent by buds, but are continually liable to reversion by seed,—that is, to the loss of their hybrid or intermediate character. Here is a still more perplexing case:—certain plants with variegated leaves, phloxes with striped flowers, barberries with seedless

[1] *Variation under Domestication*, vol. ii. p. 93.

fruit, can all be securely propagated by the buds on cuttings: but the buds developed from the roots of these cuttings almost invariably lose their character and revert to their former condition."[1]

These facts appear to show that a bud is in some degree a new plant, though less so than a seedling: and this is confirmed by the following:—

Selection applied to Bud-variation.—"To my surprise I hear from Mr. Salter that he brings the great principle of selection to bear on variegated plants propagated by buds, and has thus greatly improved and fixed several varieties. He informs me that at first a branch often produces variegated leaves on one side alone, and that the leaves are marked with an irregular edging, or with a few lines of white and yellow. To improve and fix such varieties, he finds it necessary to encourage the buds at bases of the most distinctly marked leaves, and to propagate from them alone. By following with perseverance this plan during three or four successive seasons, a distinct and fixed variety can generally be secured.

"The facts prove in how close and remarkable a manner the germ of a fertilized seed and the small cellular mass forming a bud resemble each other in function, in their powers of inheritance with occasional reversion, and in their capacity for variation of the same general nature, in obedience to the same laws."[2]

Origin of the Nectarine and the Moss-Rose.—Bud-variations, though rare when compared with seed-variations, are sometimes very decided. The nectarine has arisen thus from the peach, not gradually and through selection, but by a single act of variation, affecting not the entire tree but only one bud.[3] The common double moss-rose probably arose thus from the Provence rose, to which it is liable to revert: "for branches of the common moss-rose have several times been known to produce

[1] *Variation under Domestication*, vol. ii. p. 396.
[2] *Ibid.* voi. i. p. 411.
[3] *Ibid.* vol. i. p. 340 *et seq.*

Provence roses, wholly or partially destitute of moss." [1] Variations of this kind usually affect not an entire tree but only one bud: and yet in some cases, as in that of the nectarine, they can be truly propagated by seed: and, as might be expected, they "can generally be propagated to any extent by grafting."

Bud-variation in an Apple-tree.—The following is an equally remarkable instance of bud-variation:—"Mr. Thomas Meehan has described before the Academy of Natural Sciences of Philadelphia a case of sudden change of characters in some branches of a 'smoke-house' apple-tree which bore clusters of flowers at the ends of young shoots flowering six weeks after the ordinary blooms from spurs. This fruit, however, was very unlike the old smoke-house fruit, the fruit-stems being long and slender, and the fruit flattened. The change was so great that a botanist would have no hesitation in describing the form as a new species." [2]

Bud-variation in Hydras and in Coral.—It is worth mentioning, though not at all wonderful, that "any peculiar character presented by a compound animal is propagated by budding, as occurs with differently-coloured hydras, and, as Mr. Gosse has shown, with a singular variety of a true coral. Varieties of hydra have also been grafted on other varieties, and have retained their character." [3]

Graft-hybridism.—Grafting, like hybridization, appears to depend on some community of nature between the two species that can be thus united: [4] and this is confirmed by the possibility of graft-hybridism. Graft-hybridism is not a normal but an exceptional phenomenon; nevertheless a few remarkable instances of it appear to be sufficiently well authenticated.

Instance in a Potato.—"Dr. Hildebrand removed all the eyes from a white smooth-skinned potato, and all from a red scaly

[1] *Variation under Domestication*, vol. i. p. 379. [2] *Nature*, August 9, 1877, p. 288. [3] *Variation under Domestication*, vol. i. p. 374.

[4] See, however, note at end of chapter.

potato, and inserted them reciprocally into each other. From these eyes he raised only two plants: and of the tubers formed by them, two were red and scaly at one end, and white and smooth-skinned at the other, the middle part being white with red streaks. Hence the possibility of the production of a graft-hybrid may be looked on as established." [1]

Instance in a Rose.—"The most reliable instance known to me, with the exception of the case just given, of the formation of a graft-hybrid, is one recorded by Mr. Poynter. *Rosa Devoniensis* had been budded some years previously on a white Banksia: and from the much enlarged point of junction, whence the Devoniensis and Banksia both continued to grow, a third branch issued which partook of the character of both. It appears that rose-growers were aware that the Banksia sometimes affects other roses. Had it not been for this, it might have been suspected that this new variety was simply due to bud-variation, and occurred by mere accident at the point of junction between the two old kinds." [2]

Instance in a Carrot.—Another remarkable instance is the case of "the red and white carrot recorded by Lindley. The two roots became twisted one round the other, and finally united together. While the tops or crowns of the two carrots preserved their natural appearance above the point of union, it was very different below. The characteristics of the two roots below the union were exactly transposed. What should have been a red root became white, and the white root red. We may illustrate the case by the letter X, consisting of two lines, one thick and the other thin, crossing in the centre. Suppose the thick line to become thin below the junction, and the thin line to become thick, we shall have a change analogous to that which took place in the carrots." [3]

[1] *Variation under Domestication*, vol. i. p. 396. [2] *Ibid.* vol. i. p. 396.
[3] "Grafting," by Maxwell T. Masters, M.D., F.R.S., in the *Popular Science Review*, 1871, p. 141.

Instance in a Laburnum. Segregation of character.—It will be observed that Dr. Hildebrand's potatoes showed what Darwin calls segregation of character, each of the parent varieties being represented by one end of the hybrid potato. Another remarkable instance of the kind is *Cytisus adami*,[1] a hybrid, and as Darwin believes a graft-hybrid, between the yellow and purple laburnums. Its characteristic blossoms are dingy-red, but it is very liable to revert to both the parent forms, and "it is a surprising sight to behold mingled on the same tree-tufts of dingy red, bright yellow and purple flowers borne on branches having widely different leaves and manner of growth." This reversion to the characters of the two parents may be compared with what has been already mentioned[2] as to the difficulty of combining the characters of animal races, even when they are mutually fertile.

Segregation of character in Seed-hybrids.—The same kind of segregation is possible in a seed-hybrid. "Gallesio impregnated an orange with pollen from a lemon, and the fruit borne on the mother tree had a raised stripe of peel like that of a lemon both in colour and taste, but the pulp was like that of an orange, and included only imperfect seeds."[3] This strongly resembles the case of the hybrid potato, which was a graft-hybrid:—indeed the laws of variation, hybridism, and reversion appear to differ little between seed- and bud-propagation.

Segregation of character in the case of the Nectarine and the Peach.—A similar instance of segregation has been observed in the case of a fruit which was "three parts peach and one part nectarine, quite distinct in appearance as well as in flavour; the lines of division were longitudinal." This grew on a peach-tree, but as a nectarine was growing near, it may have been a case of seed-hybridism.[4] There are many instances of the same tree producing both peaches and nectarines: and it seems surprising

[1] *Variation under Domestication*, vol. i. p. 389.
[2] See p. 152.
[3] *Variation under Domestication*, vol. i. p. 336.
[4] *Ibid.* vol. i. 341.

that fruit of intermediate character should not be produced as a consequence of hybridism: for the nectarine being a bud-variation of the peach, the difference of race is but slight. This instance appears to be a strong confirmation of Darwin's opinion that the tendency to segregation of character depends on the variation having arisen suddenly:—in other words, that varieties that have arisen suddenly have a difficulty in mixing their characters with those of the parent race, or of other similarly arising varieties.[1]

We have now to enter on the most difficult and most interesting branch of the inquiry;—namely, the laws according to which variation occurs. On this subject we can conclude but little definitely, but we can enumerate many facts which may throw some light on each other.

Effect of Cultivation and Selection on domestic races.—Darwin appears to attach the chief importance to slow variations accumulating through ages, produced in some cases, though probably not in all, by changes in external conditions, and preserved by selection. The same principles, though applied to different circumstances, are true of domestic as of wild races. With domestic races the impulse to variation is given by cultivation and training, and the selection is effected by man, acting in the earlier periods almost unconsciously, through every one's desire to possess good specimens of the race, but afterwards consciously and methodically. The power of this kind of agency is shown in the great difference between most domestic races and their wild originals.

Origin of the Peach from the Almond.—Most cultivated plants have been so changed by long continued cultivation, that their wild originals cannot be identified with certainty. In one of the most surprising cases, however, Darwin believes that the original stock can be identified:—the peach, he thinks, is most probably

[1] See p. 153.

a modified almond. "A first-rate peach, almost globular, formed of soft and sweet pulp, surrounding a hard, much furrowed, and slightly flattened stone, certainly differs greatly from an almond, with its soft, slightly-furrowed, much flattened and elongated stone, protected by a tough greenish layer of bitter flesh." Yet the specific identity of these two was suggested to Andrew Knight, "from finding that a seedling tree raised from a sweet almond fertilized by the pollen of a peach yielded fruit quite like that of a peach:" and there are "several varieties which connect the almond with the peach." Moreover, a remarkable statement by M. Luizet has appeared in the *Revue Horticole*, that "a peach-almond grafted on a peach bore during 1863 and 1864 almonds alone, but in 1865 bore six peaches and no almonds:" and another similar instance is quoted.[1]

Equally great Variations among domestic Animals. The Pigeon.—Changes as remarkable as this have occurred under domestication among animals. There is every reason to believe that all the domestic races of pigeons are descended from the wild rock-pigeon, *Columba livia;* yet of these Darwin says:—"With the exception of a few forms, I do not hesitate to affirm that some domestic races of the rock-pigeon differ fully as much from each other in external characters as do the most distinct natural genera."[2] I do not mention the dog, because, unlike the pigeon, the domestic races of the dog are probably descended from different wild species, which have formed mixed races.[3]

Selection is generally a more important agency than Cultivation. Artificial instincts are probably an exception.—In tracing the cause of any particular improvement, it is generally impossible to separate the effect of selection from that of cultivation. Cultivation, as we have seen, greatly increases the abundance of nutriment supplied to each plant; and this promotes luxuriance

[1] *Variation under Domestication*, vol. i. p. 338.
[2] *Ibid.* vol. i. p. 133. [3] *Ibid.* vol. i. p. 26.

of growth, as well as general variability. But it appears most probable that selection among small spontaneous variations has been the chief agency, because it is found that with domestic races of both plants and animals the characters which are variable in the race are those for which it is valued, and are the characters which are selected for the purpose of improving it still further.[1] The case of artificial instincts in animals, like those of the sheep-dog and the pointer, are probably an exception to this; they appear to have been implanted by generations of training; but selection must have a great influence here also, by preserving the best and getting rid of intractable subjects. Of the many wonderful things that man has done, perhaps the most wonderful is to teach the dog to tend sheep instead of devouring them.

Effects of Selection. Divergence and Convergence of character. Convergence in races of the Pig.—The general tendency of selection is to produce divergence of character in the different breeds descended from the same aboriginal race, because the points which are valued in the different races, and for which they are selected, are generally different in the different breeds. But there are few instances of the converse case, where selection among originally different races for the same qualites has led to convergence of character. "All the improved races of the pig closely approach each other in character in their shortened legs and muzzles, their almost hairless, large rounded bodies, and small tusks. We see some degree of convergence in the similar outline of the body in well-bred cattle belonging to distinct races. I know of no other such cases."[2] Darwin elsewhere mentions that "in the case of the convergent races of pigs, evidence of their descent from the two primitive (wild) stocks is still plainly retained, according to Von Nathusius, in certain bones of their skulls."[3] Selection in these cases may have been

[1] *Variation under Domestication*, vol. ii. p. 241.
[2] *Ibid.* vol. ii. p. 241.
[3] Darwin's *Descent of Man*, vol. i. p. 231.

aided by "parallel variations," of which subject we shall have to speak again.

Sudden Variations. Monstrous races. Mauchamp Sheep.—In the formation of new races, much importance belongs to sudden variations. Some of these have a partly monstrous character. One of the most interesting recorded cases of the sudden origin of a new race was "the production of a merino ram-lamb on the Mauchamp farm in 1828, which was remarkable for its long, smooth, straight and silky wool. By the year 1833, M. Graux had raised rams enough to serve his whole flock, and after a few more years he was able to sell stock of his new breed. So peculiar and valuable is the wool that it sells 25 per cent. above the best merino. It is interesting, as showing how generally any marked deviation of structure is accompanied by other deviations, that the first ram and his immediate offspring were of small size, with large heads, long necks, narrow chests and long flanks ; but these blemishes were removed by judicious crosses and selections. The long smooth wool was also correlated with smooth horns:—horns and hair are homologous structures." [1]

Otter-sheep, Bull-dog, and Pug-dog.—The otter-sheep has already been mentioned; it was in some degree monstrous, "having short crooked legs, and a long back like a turnspit dog," [2] and was cultivated for some years in the United States, where it arose, because it was unable to get over fences. Darwin says of the dog :—" Some of the peculiarities characteristic of the several breeds have probably arisen suddenly, and, though strictly inherited, may be called monstrosities ; for instance, the shape of the legs and the body in the turnspit of Europe and India; the shape of the head and the underhanging jaw in the bull-dog and pug-dog, so alike in this respect, and so unlike in all the others." [3]

[1] *Variation under Domestication*, vol. i. p. 100.
[2] *Ibid.* vol. i. p. 100. [3] *Ibid.* vol. i. p. 38.

Independent Similarities. Pigs with solid hoofs. Pigs with jaw-appendages.—This last is an interesting case of parallel variations, or what Mr. Mivart calls "independent similarities of structure," that is to say, resemblances not due to kindred. But a much more remarkable instance of the same is to be found among pigs. "From the time of Aristotle till now, solid-hoofed swine have occasionally been observed in various parts of the world. Although the peculiarity is strongly inherited, it is hardly probable that all the animals with solid hoofs have descended from the same parents; it is more probable that the same peculiarity has appeared at various times and places."[1] This cannot be due to reversion, because the pig belongs to the cloven-footed order, and no kindred species has solid hoofs. A still more curious instance of a monstrous variation occurring now and then in a species, is the cartilaginous jaw-appendages occasionally found in all races of pigs; this character also appears not to be due to reversion, for no wild species is known to have them; but as it is not strictly inherited, it has little bearing on the question of the origin of species.[2]

Niata Cattle.—But perhaps the most remarkable instance of a semi-monstrous race which breeds truly, is that of the niata cattle of South America. Their origin is not precisely known, but probably they began in a sudden variation, like other semi-monstrous breeds.

"This breed bears the same relation to other breeds (of cattle) as bull-dogs or pugs to other dogs. The forehead is very short and broad, with the nasal end of the skull, together with the whole plane of the upper molar teeth, curved upwards. The lower jaw projects beyond the upper, and has a corresponding upward curvature. It is an interesting fact that an almost similar conformation characterizes the gigantic extinct Sivatherium of India, and is not known in any other ruminant. The upper lip is much drawn back, the nostrils are seated high up

[1] *Variation under Domestication*, vol. i. p. 75.
[2] *Ibid.* vol. i. p. 75.

and are widely open, the eyes project outwards, and the horns are very large. In walking, the head is carried low, and the neck is short. The hind-legs appear to be longer, compared with the fore-legs, than is usual. The exposed incisor teeth, the short head and upturned nostrils, give these cattle the most ludicrous self-confident air of defiance. The skull which I presented to the College of Surgeons has been thus described by Professor Owen:—

"'It is remarkable from the stunted development of the nasals, premaxillaries, and fore-part of the lower jaw, which is unusually curved upwards to come into contact with the premaxillaries. The nasal bones are about one-third the ordinary length, but retain almost their normal breadth. The triangular vacuity is left between them, the frontal and lachrymal, which latter bone articulates with the premaxillary, and thus excludes the maxillary from any junction with the nasal.'

"So that even the connexion of some of the bones is changed. Other differences might be added: thus, the plane of the condyles is somewhat modified, and the terminal edge of the premaxillaries forms an arch. In fact, on comparison with the skull of a common ox, scarcely a single bone presents the same exact shape, and the whole skull has a wonderfully different appearance."[1]

Sudden Origin of Varieties in Plants.—The following cases of the sudden origin of varieties are mentioned on the authority of Naudin:[2]

The Poppy.—"The first case mentioned is that of a poppy which took on a remarkable variation in its fruit, a crown of secondary capsules being added to the normal central capsule. A field of such poppies was grown, and M. Göppert, with seed from this field, obtained still this monstrous form in great quantity.

[1] *Variation under Domestication*, vol. i. p. 89.

[2] Quoted in the *Quarterly Journal of Science*, October 1867, from the *Comptes Rendus*.

Ferns.—"Deformities of ferns are sometimes sought after by fern-growers. They are now always obtained by taking spores from the abnormal parts of a monstrous fern, from which spores, ferns presenting the same peculiarities invariably grow.

Datura tatula.—"The most remarkable instance is that observed by M. Godron of Nancy. In 1861, that botanist observed, among a sowing of *Datura tatula*, the fruits of which are very spinous, a single individual of which the capsule was perfectly smooth. The seeds taken from this plant all furnished plants having the character of this individual. The fifth and sixth generations are now growing without exhibiting the least tendency to revert to the spinous form. More remarkable still, when crossed with the normal *Datura tatula* hybrids were produced, which in the second generation reverted to the two original types, as true hybrids do."

Townshend M. Hall on rapid Variation in Ferns.—The following are remarkable instances, not of sudden variation, but of variation of the ordinary kind now going on with extraordinary rapidity among ferns in England:—

Mr. Townshend M. Hall, at the British Association in 1870, "gave some results of his observations with reference to the increasing prevalence of abnormal structures among certain species of ferns in the south-west of England, especially in Devonshire. His remarks did not relate to the varieties of ferns subjected to cultivation, but to the changes which appear to have taken place during the last few years among those common species which abound in every wood and hedgerow. From the profusion in which they grow in the south-west of England, there are several species which afford an excellent indication of that change which is rapidly effecting an alteration among this tribe of plants.

"*Scolopendrium vulgare* appears to have been among the first to assume bifid and multifid forms; and so rapidly have they increased, either by sowing the spores or by inoculation, that there are now many localities where plants bearing abnormal

fronds are the rule. Other common forms of this fern are the crisped and the crested, narrow and ramose. Many other ferns have recently appeared in the Devonshire lanes with bifurcated leaves. The author mentioned a plant of *Polystichum angulare* which he transplanted from a neighbouring lane into his fernery a few years ago, when it had only two or three fronds bifurcated, and the succeeding year brought them out with a thickly-crested multifid termination, while a fresh variation appeared in the bifurcation of each of the pinnæ or side leaves. In another season the pinnæ also had become crested, and so the whole plant has gone on, becoming more and more divided and subdivided, until all its original character has passed away; and the twenty-nine fronds of which it at present consists, which ought in a normal state to have only as many terminations, are now so multiplied, that on the smallest and least crested are one hundred and thirty-seven small but well-defined terminations, while some of the larger leaves have upwards of double that number. The plant has never been moved or meddled with, and the only attention it received was an occasional watering." [It probably, however, was kept clear of weeds, and this, by increasing the supply of nourishment, is, according to Darwin, of great importance as a stimulus to variation.] "The fern which in its natural state is at present undergoing the greatest amount of change is the *Pteris aquilina*, or common brake. The observations of the bifid and multifid forms of this species date from five years ago, up to which time the author knew of only one locality where an abnormal plant could be met with. Now the variations have so increased that even in this short time this species bids fair to outstrip *Scolopendrium vulgare*."

These changes are independent of natural selection.—It is to be observed that these changes appear to be in no degree due to natural selection, because it is impossible to believe that they can be of any advantage to the species. One form of leaf or one mode of branching must in almost all cases be as beneficial as another.

Extra number of multiple parts: Teeth in the Dog and Horse, Ribs in the Horse.—There are some variations which from the nature of the case must occur suddenly and all at once when they occur at all: I mean when an unusual number of some multiple part appears. Extra teeth appear to be not very uncommon. "The dog has properly six pairs of molar teeth in the upper jaw, and seven in the lower, but several naturalists have not rarely seen an additional pair in the upper jaw, and Professor Gervais says there are dogs which have seven pairs of upper and eight lower teeth. De Blainville has given full particulars of these deviations in the number of the teeth, and has shown that it is not always the same tooth which is supernumerary."[1] "Of horses, Mr. Brown writes, that he has several times noticed eight permanent incisors instead of six in the jaw. The number of ribs is properly eighteen, but Youatt asserts that not unfrequently there are nineteen on each side, the additional one being the posterior rib."[2]

Monstrous Variations are probably always Sudden, but not the converse. Begonia frigida.—Though it appears probable that monstrous varieties have always arisen suddenly, by a single act of variation, yet the converse is not true; variations may be sudden but not monstrous. "*Begonia frigida* properly produces male and female flowers on the same fascicles: and in the female flowers the perianth is superior; but a plant at Kew produced, besides the ordinary flowers, others which graduated towards a perfect hermaphrodite structure: and in these flowers the perianth was inferior. Professor Harvey says:—'Had it occurred in a state of nature, and had a botanist collected a plant with such flowers, he would not only have placed it in a distinct genus from Begonia, but would probably have considered it the type of a new natural order.' This modification cannot in one sense be considered a monstrosity, for analogous structures naturally occur in other orders, as with Saxifrages and

[1] *Variation under Domestication*, vol. i. p. 34.
[2] *Ibid.* vol. i. p. 50.

Aristolochiaceæ. Seedlings from the normal flowers produced plants which bore, in about the same proportion as the parent plant, hermaphrodite flowers having inferior perianths. These, fertilised with their own pollen, were sterile." [1]

Variety of "Cucurbita maxima."—This was a case of bud-variation, as is shown by the plant which produced the new variety, having also produced flowers of the common kind. But a similar variety may arise by a seed-variation. Thus, "Naudin describes a Chinese variety of *Cucurbita maxima* which had a perfectly free or superior ovary, whereas it is superior elsewhere in the Cucurbitaceæ, and in the nearly allied orders." [2] It appears much more likely that a variety of *Cucurbita* should have originated in a seed- than in a bud-variation.

Identical Variation on different occasions. The Peach and the Nectarine.—It is one of the most wonderful of the facts with which we have to do, that the same variation may occur at various times and places, under circumstances which appear to exclude any explanation of the facts by either reversion or hybridism. The nectarine has already been mentioned as arising by bud-variation from the peach, and it is now to be mentioned that "six well-known varieties and several other unnamed varieties have once suddenly produced nectarines by bud-variation." [3] "We have excellent evidence of peach stones producing nectarine trees; nectarine stones producing peach trees; the same tree producing peaches and nectarines;—peach trees suddenly producing nectarines by bud-variation;—such nectarines producing nectarines by seed;—fruit part nectarine and part peach;—and one nectarine tree first bearing (such) half-and-half fruit, and subsequently true peaches. As the peach came into existence before the nectarine, it might be expected

[1] *Variation under Domestication*, vol. i. p. 365.
[2] Bennett's translation of Sachs's *Botany*, p. 827.
[3] *Variation under Domestication*, vol. i. p. 342.

from the law of reversion that nectarines would give birth to peaches oftener than peaches to nectarines, but this is by no means the case." [1]

Similar case in the Sweet Potato.—There appears to be an instance, like that of the peach and the nectarine, of identical bud-variations showing themselves at different times and places, in the sweet potato (*Convolvulus batatas*). Mr. Meehan says:—"I have evidence of bud-variation in which there is no possibility of hybridism;—a root of the common sweet potato, in which some of the tubers are of the red Bermuda, and the others of the white Brazilian variety. The sweet potato never flowers in this part of the country, so that seminal power could have had no influence whatever on the phenomenon. Even in the South (of the United States), and I believe elsewhere, where the plant is cultivated for its roots, it rarely flowers; and I think there is little doubt but that the whole ten or twelve varieties under culture have originated without seed, and in the way we see them here. The points I wish to make are:—

1st. That identical varieties sometimes appear in localities unfavourable to the idea of a common centre of origin.

2nd. Varieties have originated in which probably no hybridism or any seminal agency operated.

3rd. Varieties have certainly originated in the sweet potato by evolution, without seminal agency, and the same variety in this way has appeared in widely separated districts.

4th. As the discoveries of Darwin have shown, in many cases, varieties to be the parents of species, species may originate in widely separated localities by bud-variation." [2]

Distinct Origins of the Moss-Rose.—The moss-rose likewise appears to have originated at different times and places. Dr. Masters says:—"A plant which ordinarily has its leaves and

[1] *Variation under Domestication*, vol. i. p. 341.

[2] Philadelphia Academy of Natural Sciences, 29th November, 1870, reported in *Nature* 16th February, 1871.

its younger branches invested with a eoating of hairs, all on a sudden produces a shoot on which the leaves are destitute of such elothing, or *viee versâ*. Some moss-roses have arisen from plain-leaved varieties in this manner." [1]

The black-shouldered Peaeoek.—The most remarkable known instanee of the sudden appearanee of a new form, is that of the "black-shouldered peacock," whieh has been regarded by the eminent ornithologist Mr. Sclater as a true species in the ordinary acceptation of the word ;—but Darwin thinks the evidenee is suffieient to show that it has been hatched on five different occasions, in England, from the eggs of the common peacoek. It is not a hybrid, and there is no evidenee of its being a reversion to any ancestral form. They "differ conspieuously from the common peacoek in the eolour of the secondary wing-feathers, seapulars, wing-eoverts, and thighs; the females are mueh paler, and the young likewise differ. They can be bred perfectly true."[2]

Importance of these eases for the Origin of Speeies.—The instances whieh have been mentioned, of new forms coming into existence by a single act of variation, appear to throw a real light on the origin of species, and to make it probable that in many, perhaps in most, cases, speeies in the wild state have like these arisen at once, and not by a slow process of natural selection of small irregular variations through many generations. From this point of view the fact is very important, that the nectarine has not more tendency to revert back to the peach than the peach to go on varying into nectarines. This seems to show that the nectarine is established as a species; and that it is possible by a single act of variation not only to establish a new form, but in a great degree to get rid of the tendeney to reversion to the parent form.

1 "Bud-Variation," by Maxwell T. Masters, M.D., F.R.S., in the *Popular Science Review*, 1872, p. 244.

2 *Variation under Domestication*, vol. i. p. 290.

Laws of the Correlation of Growth.—Every species, or at least every genus, is generally distinguished from others, not by a single character but by an assemblage of characters; and it can scarcely be doubted that there must be some connexion—some bond of correlation—between the several characters of a species; but in the vast majority of cases the nature of the correlation is quite unknown. The following are a few instances in which the principle that determines the correlation appears to be in some degree made out.

Instances in the head of Fowls.—"A large crest of feathers seems always accompanied by a great diminution or almost absence of the comb. A large beard is similarly accompanied by diminished or absent wattles. These cases apparently come under the law of compensation or balancement of growth. That is to say, that as the supply of nutritive substance is always a limited quantity, excess of growth in one direction must be compensated by retrenchment in another. A large beard beneath the lower jaw and a large top-knot on the skull often go together. The comb, when of any peculiar shape, as in Horned, Spanish, and Hamburgh fowls, affects in a corresponding manner the underlying skull; and we have seen how wonderfully this is the case with crested fowls when the crest is largely developed." [1] "With the protuberance of the frontal bones the shape of the internal surface of the skull, and of the brain, is greatly modified. The presence of a crest influences in some unknown way the development of the ascending branches of the premaxillary bone, and of the inner processes of the nasal bones: and likewise the shape of the external orifice of the nostrils." [2]

Perforated Skulls.—"Polish fowls have a large tuft of feathers on their heads, and their skulls are perforated by numerous holes, so that a pin can be driven into the brain without touching

[1] "Crested or Polish breed. Head with a large rounded crest of feathers, supported on a hemispherical protuberance of the frontal bones, which includes the anterior part of the brain."—*Variation under Domestication*, vol. i. p. 227.

[2] *Ibid.* vol. i. p. 274.

any bone. That this deficiency of bone is in some way connected with the tuft of feathers, is clear from tufted ducks and geese likewise having perforated skulls."[1] I quote this case chiefly on account of its strangeness. Darwin remarks :—"This case would probably be considered by some authors as one of balancement or compensation."

Correlated Variation. Homologous parts varying alike.—The nature of the correlation, in many cases, comes under the intelligible principle which Darwin calls correlated variation—that is to say, that when one part varies, others often vary in a corresponding manner. Thus, "in the serpent melon, which has a narrow tortuous fruit above a yard in length, the stem of the plant, the peduncle of the female flower, and the middle lobe of the leaf, are all elongated in a remarkable manner. On the other hand, several varieties of *Cucurbita* which have dwarfed stems, all produce, as Naudin remarks, leaves of the same peculiar shape. Mr. G. Maw informs me that all the varieties of the scarlet Pelargoniums which have contracted or imperfect leaves have contracted flowers; the difference between 'Brilliant' and its parent 'Tom Thumb' is a good instance of this."[2]

It is another instance of the same principle, that deformities of the hands and of the feet, or any peculiarities of those parts, such as unusual length or shortness, often accompany each other.

Curious case in Pigeons.—In connexion with this I quote from Darwin :—"The following common case of correlation long appeared to me utterly inexplicable. In pigeons of any breed, if the legs are feathered, the two outer toes are partially connected by skin." This is a case of correlated variation of homologous parts. The two outer toes are those corresponding to the digits forming the extremity of the wing, which are "completely united and enclosed by skin:" so that when the

[1] *Variation under Domestication*, vol. ii. p. 332.
[2] *Ibid.* vol. ii. p. 330.

legs resemble the wings in being feathered, the resemblance extends to the skin, uniting those two toes.

Union of homologous parts.—It appears to be a well-established law that homologous parts have a tendency to cohere, and even to become fused together. "When homologous parts, whether belonging to the same or to two distinct embryos, are brought during an early stage of development into contact, they often blend into a single part or organ. This complete fusion indicates some natural affinity between the parts, otherwise they would simply cohere. This tendency to complete fusion is not a rare or exceptional fact. It is exhibited in the most striking manner by double monsters."[1] The same principle however appears to illustrate normal morphology. "As Geoffroy St. Hilaire remarks, these facts illustrate in an admirable manner the normal fusion of various organs which during an early embryonic period are double, but which afterwards always unite into a single median organ."[2] The same principle is however applicable to other cases than those of double organs; thus, the segments of the external covering, which in the lower crustacea are distinct, are fused together in crabs; and in flowers the petals, which in the earliest forms were most probably distinct, have in many orders grown together into a tube, forming what is called gamopetalous structure.

Gamopetalous Flowers. Insertion of the Stamens.—In connexion with this we may add, that, by some inexplicable correlation, gamopetalous flowers generally have the stamens inserted in the corolla, while in polypetalous flowers they are generally inserted either in the calyx or under the pistil. It is to be remarked that any change in the insertion of the stamens is a variation which, from the nature of the case, must have arisen suddenly.

The Laws of Correlation do not act perfectly. The Beak and Tongue in Pigeons.—But whatever the laws of correlation may

[1] *Variation under Domestication*, vol. ii. p. 339. [2] *Ibid.* vol. ii. p. 341.

be, it is important to observe that, under the conditions of domestic races at least, and in the comparatively short time during which man has been acting on them by selection, these laws do not appear to secure that the adaptation of all the parts of the organism to each other shall be perfect. Darwin says of pigeons :—

"The beak is readily acted on by selection, and with its increased or diminished length the tongue increases, but not in due proportion; for in a barb and in a short-faced tumbler, both of which have very short beaks, the tongue, taking the rock-pigeon as the standard of comparison, was proportionally not shortened enough, while in two carriers and a runt, the tongue, proportionally with the beak, was not lengthened enough." [1]

Parallel Variation.—One of the most important laws is that of "analogous or parallel variation. By this term I wish to express that similar characters occasionally make their appearance in the several varieties or races descended from the same species, and, more rarely, in the offspring of widely distinct races." [2]

Varieties of a Species mocking allied Species. Fowls, Ewes, Cats, Rabbits.—Characters which are variable in a species are variable in allied species,[3] and, what is much more wonderful, "the varieties of one species frequently mock distinct species." [4] Thus, "several breeds of the fowl have either spangled or pencilled feathers. These cannot be derived from the parent species, *Gallus bankiva*, though of course it is possible that an early progenitor of this species may have been spangled, and a still earlier or a later progenitor may have been pencilled; but, as many gallinaceous birds are spangled or pencilled, it is a more probable view that the several domestic breeds have acquired this kind of plumage from all the members of the family inheriting a tendency to vary in like manner. The same principle may account for the

[1] *Variation under Domestication,* vol. i. p. 168.
[2] *Ibid.* vol. ii. p. 348.
[3] *Ibid.* vol. ii. p. 351.
[4] *Ibid.* vol. ii. p. 351.

ewes in certain breeds of sheep being hornless, like the females of some other hollow-horned ruminants; for certain domestic cats having slightly tufted ears like the lynx; and for the skulls of domestic rabbits often differing from each other in the same characters by which the skulls of various species of *Lepus* differ."[1]

"*Similar cases among Plants. Peach and Nectarine. Melon.*— "The nectarine is the offspring of the peach; and the varieties of both these trees offer a remarkable parallelism in the fruit being white, red, or yellow-fleshed—in being clingstones or freestones—in the flowers being large or small—in the leaves being serrated or crenated, furnished with globose or reniform glands, or quite destitute of glands. It should be remarked that *each variety of the nectarine has* not *been derived from a corresponding variety of the peach.*"[2] "Three species of *Cucurbita* have yielded a multitude of races, which correspond so closely in character that, as Naudin insists, they may be arranged in an almost strictly parallel series. Several varieties of the melon are interesting from resembling in important characters other species, either of the same genus or of allied genera. Thus, one variety has fruit so like, both externally and internally, the fruit of a perfectly distinct species, namely the cucumber, as hardly to be distinguished from it; another has long cylindrical fruit twisting about like a serpent; in another the seeds adhere to portions of the pulp; in another, the fruit, when ripe, suddenly cracks and falls to pieces: and all these highly remarkable peculiarities are characteristic of species belonging to allied genera. We can hardly account for the appearance of so many unusual characters by (any hypothesis of) reversion to a single ancient form; but we must believe that all the members of the family have inherited a nearly similar constitution from an early progenitor."[3]

[1] *Variation under Domestication*, vol. ii. p. 350.
[2] *Ibid.* vol. ii. p. 348. The italics are mine.
[3] *Ibid.* vol. ii. p. 349.

Similar effects from Disease.—Disease, being a change of conditions, sometimes acts as a stimulus to variation. Darwin mentions the remarkable effects which parasitic fungi, acting it appears simply as excitors of disease, sometimes produce on plants. Reissek has described a Thesium affected by an Œcidium, which was greatly modified, and assumed some of the characteristic features of certain allied species, or even genera. "Suppose," says Reissek, "the condition originally caused by the fungus to become constant in the course of time, the plant would, if found wild, be considered as a distinct species, or even as belonging to a new genus."[1] Here it will be observed that a case of variation produced by disease was not irregular, as might be expected, but took the direction of "parallel or analogous variation."

Reversion caused by Disease.—With this may be compared the case of a Sebright hen bantam, which, as she grew old, became diseased in her ovaria, and assumed male characters. This is common enough, but in the present case the male characters assumed were not only those of her own breed, "but she acquired in addition well arched tail-feathers quite a foot in length, saddle-feathers on the loins and hackles on the neck," which do not belong to the Sebright bantam, but were evidently a reversion to the characters of the common bantam and Polish fowl, from which the Sebright breed is descended.[2] In this case disease gave an impulse to variation, and variation took the form of reversion.

Varieties of Forest-trees.—All the parallelisms in variation mentioned above are between nearly allied species or varieties. But there are many such parallelisms between species which have not any near or special connexion. Darwin says of the varieties of forest trees:—"The occurrence in trees belonging to widely different orders, of weeping and fastigate (or pyramidal)

[1] *Variation under Domestication*, vol. ii. p. 284.
[2] *Ibid.* vol. ii. p. 54.

varieties, and of trees having deeply cut, variegated, and purple leaves, shows that these deviations from structure must result from some very general physiological laws." [1] Darwin is of opinion that each of these varieties is not the result of any influence accumulated by natural selection, but of a single act of variation; and Dr. Masters is of the same opinion.[2]

Geographical Variations. European and American Trees.—We have in connexion with this subject to mention an influence which appears to be of much importance though scarcely at all intelligible, namely the influence of locality;—geographical variation. "Mr. Meehan, in a remarkable paper, compares twenty-nine kinds of American trees, belonging to different orders, with their nearest European allies, all grown in close proximity in the same garden, and under as nearly as possible the same conditions. In the American species, Mr. Meehan finds, with the rarest exceptions, that the leaves fall earlier in the autumn and assume before falling a brighter tint; that they are less deeply toothed or serrated; that the buds are smaller; that the trees are more diffuse in growth and have fewer branchlets; and lastly, that the seeds are smaller—all in comparison with the corresponding European species. Now, considering that these trees belong to distinct orders, it is out of the question that the peculiarities just specified should have been inherited in the one continent from one progenitor, and in the other from another progenitor; and considering that these trees inhabit widely different stations, these peculiarities can hardly be supposed to be of any special service to the two series in the Old and New Worlds; therefore these peculiarities cannot have been naturally selected. Hence we are led to infer that they have been defi-

[1] *Variation under Domestication*, vol. i. p. 362. In another place Darwin mentions variegation in leaves as a somewhat morbid character, and "generally to result from a feeble or atrophied condition of the plant."—Vol. ii. p. 168. There is, however, no contradiction in describing a morbid variation as a genuine variation, illustrating physiological laws.

[2] See Dr. Masters's already quoted paper on "Bud-Variation," p. 248.

nitely caused by the long-continued action of the different climate of the two continents on the trees." [1]

Local appearance of Variegation in the Strawberry.—The case of strictly and narrowly local variations is even more curious. "Mr. Salter, who is well known for his success in cultivating variegated plants, informs me that rows of strawberries were planted in his garden in 1859 in the usual way, and at various distances in one row, several plants simultaneously became variegated; and what made the case more extraordinary, all were variegated in precisely the same manner. These plants were removed; but during the three succeeding years other plants in the same row became variegated, and in no instance were the plants in any adjoining row affected." [2] Darwin mentions some other instances of particular localities that promote variegation, but none so remarkable as this.

Local Variations in Mimulus and other Flowers.—Variegation is an abnormal character, but individuals when cultivated together frequently show a tendency to assume the same normal variations, in a way which is evidently due to all the individuals being subject to the same conditions. This is obviously a fact of the same kind with geographical or local variation. Darwin, in his experiments on the effect of cross- and self-fertilization on *Mimulus luteus, Ipomœa purpurea, Dianthus caryophyllus,* and *Petunia violacea*—species which are commonly very variable in colour—found that all the flowers of each species, when cultivated together for some generations, became almost uniform; and the uniformity was more nearly perfect where the pollen of other flowers was excluded so as to ensure self-fertilization, than where intercrossing was permitted. This appears to show that uniformity of conditions is a most powerful cause of uniformity of character; and that in these

[1] *Variation under Domestication*, vol. ii. p. 281. Mr. Meehan's paper, referred to in the text, is in the *Proceedings of the Academy of Natural Science of Philadelphia*, 28th January, 1862. [2] *Ibid.* vol. ii. p. 274.

cases, contrary to what might be expected, the slight stimulus to variation from fertilization by the pollen of a different flower in the same bed, was sufficient to overpower the tendency to uniformity due to free intercrossing. The variety of colour was restored by a cross with a different stock.[1]

Variations occurring in particular years.—Some instances are recorded of variations occurring in particular years;—the agency at work here, whatever it is, probably resembles that which produces local varieties, but appears to be more energetic. "A famous amateur asserts that in 1861 many varieties of the rose came so untrue in character that it was hardly possible to recognise them. The same amateur states that in 1862 two-thirds of his auriculas produced central trusses of flowers, and these remarkable for not keeping true."[2] "In 1845 the editor of the *Gardener's Chronicle* remarked how singular it was that this year many calceolarias tended to assume a tubular form."[3]

Appearance of a new variety of deer in the wild state.—Most of the facts described in this chapter are facts of variation under domestication and culture, but I shall conclude with one which appears to be the recorded origin of a new variety at least, if not a new species, in the wild state. Darwin says:—

"A writer in an excellent American journal says that he has hunted for the last twenty-one years in the Adirondacks, where the *Cervus virginianus* abounds. About fourteen years ago he first heard of *spike-horn bucks.* These became from year to year more common; about five years ago he shot one, and subsequently another, and now they are frequently killed.

"'The spike-horn differs greatly from the common antler of *Cervus virginianus.* It consists of a single spike, more slender than the antler, and scarcely half as long, projecting forward from the brow, and terminating in a very sharp point. It gives

[1] *Cross- and Self-Fertilization*, pp. 306, 307.
[2] *Variation under Domestication*, vol. ii. p. 273.
[3] *Ibid.* vol. ii. p. 274.

a considerable advantage to its possessor over the common buck. Besides enabling him to run more swiftly through the thick woods and underbrush (every hunter knows that does and yearling bucks run much more rapidly than the large bucks when armed with their cumbrous antlers), the spike-horn is a more effective weapon than the common antler. With this advantage the spike-horns are gaining on the common bucks, and may in time entirely supersede them in the Adirondacks. Undoubtedly the first spike-horn buck was merely an accidental freak of nature. But his spike-horns gave him an advantage, and enabled him to propagate his peculiarity. His descendants, having a like advantage, have propagated the peculiarity in a constantly increasing ratio, till they are slowly crowding the antlered deer from the region they inhabit.' "[1]

In the present chapter I have endeavoured to give a slight summary of the more important of the conclusions to be derived from the vast mass of facts recorded by Darwin, giving, with the conclusions, a few specimen facts, chiefly taken from his work on *Variation under Domestication.* In the following chapters I shall endeavour to show what use may be made of them in elucidating the great facts of classification and morphology. Let me add, however, that I have been induced to write the present summary not only for the sake of the light these facts may throw on wider laws, but also by the great interest of the facts themselves.

[1] *Descent of Man,* vol. ii. p. 255. The quotation made by Darwin is from the *American Naturalist,* December, 1869, p. 552.

NOTE.

GRAFTING AND PARASITISM.

It is obvious that the possibility of hybridization depends on community of nature between the parents ; and the possibility of grafting one species on another seems to depend on the same. Nevertheless, we are met by this fact, which is opposite to what might have been expected, and in our present state of knowledge seems altogether anomalous;—that the union of species by grafting can be effected within very much wider limits than their hybridization. "The spur of a cock, after being inserted into the eye of an ox, lived for eight years, and acquired a weight of nearly fourteen ounces."[1] "Dr. Ollier inserted a piece of periosteum from the bone of a young dog under the skin of a rabbit, and true bone was developed."[2] "M. Philipeaux grafted the tooth of a guinea-pig just born into the head of a young cock, and it lived and grew."[3] Perhaps these are rather analogous to parasitism, as that of the mistletoe on the oak or the apple-tree, than to true grafting : and this appears to be Darwin's view, for he quotes from Virchow the opinion that "every single epithelial and muscle-fibre cell leads a sort of parasitical existence in relation to the rest of the body."[4] This view of these facts of animal grafting is perhaps supported by what we know of the nutrition of the Rhizocephala, animals which in their larval state are small entomostracan crustaceans, but afterwards become parasitic on other crustaceans, lose every crustacean character, and are nourished by a kind of root (whence their name) which they send into the tissues of their victims.[5] But wherein consists the difference between parasitism and true grafting? Some fundamental difference does appear to exist, for with cultivated plants the possibility of grafting seems to depend, like hybridism, on some degree of community of nature.

[1] Stated in *Variation under Domestication*, vol. ii. p. 369, on the authority of Mantegazza.

[2] *Ibid.* vol. ii. p. 369.

[3] *Nature*, July 28, 1870, p. 262.

[4] *Variation under Domestication*, vol. ii. p. 369.

[5] See Fritz Müller's *Facts for Darwin.*

CHAPTER XII.

THE SUFFICIENCY OF NATURAL SELECTION CONSIDERED.

The Facts of the previous Chapter throw little light on the Origin of Species.—It is impossible to question the interest and importance of the facts respecting variation which Darwin has collected, and of which a selection, rather than a summary, has been given in the preceding chapter. Nevertheless it will be found that they throw less light on the problem of the origin of species and characters than might be supposed on a first examination.

Graft-hybrids are Unknown under Nature, and Common Hybrids are Rare, from the Local Separation of Varieties.—From a physiological point of view it is important to know that the formation of a graft-hybrid is possible, but to the present question it appears to contribute nothing, because it seems scarcely possible that a graft-hybrid can ever be formed in a state of nature. We have every reason to believe also that ordinary hybridism, though not unknown in a state of nature, is very rare. The tendency of distinct races among animals is to herd apart; and though with vegetables the element of will does not enter, yet their races, as well as those of animals, are in most cases kept from intermixture by the fact, which is generally though not invariably true of both kingdoms, that varieties are local. Races nearly enough allied to breed together seldom inhabit the same country and haunt the same stations.[1]

[1] "The more permanent varieties are generally found, so far as I can discover, inhabiting distinct stations, such as highland or lowland, dry or moist districts.

Reversion is Rare under Nature. Instances: Peloric Flowers; Larval Generation of Aphis; Biconcave Vertebræ of Ichthyornis.—It seems probable also that reversion is rare under nature, though it is not unknown. The existence of peloric or "regular" species among genera of flowers which are usually "irregular" is no doubt due to reversion.[1] A much more remarkable case is the larva of the Aphis (or plant-louse) propagating non-sexually—a character which appears to belong to no other genus of the same order of Insects. This appears explicable only as a reversion to the character of some very remote ancestor among the lower Crustacea, or perhaps still further back. Non-sexual generation is universal among the lowest organisms, but is rare among the true Insects, and its reappearance in Aphis is perhaps due to abundant food and inactive habits of life. But the most wonderful instance of reversion that I can mention is the case of Ichthyornis, a fossil bird which has the fish-like character of biconcave vertebræ[2] (that is to say, vertebræ concave both before and behind). This must be inherited from the fishes which were the ancestors of all air-breathing vertebrates, and must be inherited through the Dinosaurians, an extinct order of Reptiles which present the nearest approximation to Birds;—and yet the vertebræ of the Dinosaurians are not biconcave.

The chief Stimulus to Variation is Change of Conditions, which has often occurred in Geological Time.—We have seen that

Moreover, in the case of animals which wander much about, and cross freely, the varieties seem to be generally confined to distinct regions."—*Origin of Species*, p. 169.

"Within the same area two varieties may long remain distinct, from haunting different stations, from breeding at slightly different times, or from the individuals of each variety preferring to pair together."—*Ibid.* p. 81.

[1] See p. 139.

[2] "Prof. Marsh has called attention to a new sub-class of fossil birds from the cretaceous shales of Kansas. The specimens, while preserving the scapular arch, wing- and leg-bones of the true bird-type, present the very aberrant conditions of having biconcave vertebræ and well-developed teeth in both jaws. These teeth are quite numerous and implanted in distinct sockets. . . . The sternum has a carina and elongated articulations for the coracoids. . . . The last sacral vertebra is large, so it may have carried a tail."—*Nature*, 20th February, 1873.

mixture of race, and change in the conditions of life, are the two great stimuli to variation; and it now appears that the former of these two scarcely acts at all in a state of nature. We must therefore conclude that so far as variability is due to any especial and assignable cause, it must be chiefly due to changes in the conditions of life; and we know that these must have occurred in countless cases throughout geological time. A change of climate in the country inhabited by any species, or a change in the entire character of the vegetation such as that from forest to prairie, or the introduction of some new kind of food, differing from the old either in its effect on the constitution or in the habits of life necessary to obtain it; or migration to a new country with different climate, vegetation, or food from that to which the species was accustomed; would constitute a change in the conditions of life which, if not so great as to be destructive, would give a stimulus to variation.

Twofold Effect of such Stimulus.—The effect of such a change in the conditions of life will be twofold; it will stimulate variation,—that is to say, it will tend to form incipient varieties,—and it will provide places in the economy of nature which in all probability can be better filled by new varieties than by the original race. To use the language of a different science, the change in the conditions of life will produce both a supply of new varieties and a demand for them.

Variability caused by Excess of Food.—Moreover, excess of food is, according to Darwin's belief, a fruitful cause of variability.[1] He speaks of this in the case of domestic animals. As a general rule, it is not probable that organisms in a state of nature should have an excess of food, because all places are full, population presses on the means of subsistence, and there is a struggle for existence;—but special cases must in geological time often occur, due to the migration of a species for the first time into

[1] See p. 134.

a region abounding with food, when it enjoys an excess of food for some generations. In such a case, the stimulus to variation derived from an excess of food will co-operate with that derived from change of country.

The Dodo.—The Dodo, which has been already mentioned,[1] is no doubt an instance of this. That very large and almost wingless bird was of the pigeon tribe, and inhabited the Mauritius, where, before the arrival of Man, the fruits of the trees supplied it with abundant food, and it appears to have had no enemies. We can scarcely doubt that the species was descended from a few individuals of some species of flying pigeon which was blown across the ocean to the Mauritius, where abundance of food promoted variation, and all the circumstances of life promoted the formation of a species with such characters as those of the Dodo.

Action of Natural Selection.—We go on to consider the question how natural selection will act.

It is obvious that when a variation is neither beneficial nor injurious to its possessor, natural selection will have nothing to act on, and the variety will be perpetuated or will die out according to the purely vital laws of variation and hereditary transmission. When a variation is injurious, the action of natural selection will prevent it from being perpetuated. When it is beneficial, on the contrary, the same agency will tend to perpetuate it. The mode of action whereby natural selection will tend to perpetuate beneficial variations is, however, a subject on which there is almost as much to be said as on the laws of variation themselves.

Professor Tait on the Improbability of the Preservation of Single Variations.—We go on to show the difficulty of believing that when favourable variations occur, they will be preserved by natural selection to the extent required by the

[1] See p. 131.

theory. Darwin, in the earlier editions of his *Origin of Species*, constantly took it for granted that the action of natural selection was altogether unerring—that it was absolutely certain to preserve those individuals which present favourable variations. There is here an important flaw in the argument, which, so far as I am aware, was first pointed out by Prof. Tait,[1] of the University of Edinburgh; and this, we may remark, is a good instance of the service that an able man may do to a science which is not his own, and of which he does not know the details. Prof. Tait has pointed out that no favourable variation can give to any single individual possessing it the certainty of surviving and leaving offspring; all it can give is an extra chance, and in many, perhaps in most, cases, a very small extra chance. Among all organisms the chances are against any one individual that is born growing up to maturity: among many, and those not the lowest tribes, the chances are hundreds to one; and if, as Darwin maintains, all variations are singly but small, what will be the value of the extra chance which some favourable variation will give its possessor in the struggle for existence? If the chances are a hundred to one against any single individual of the unimproved species surviving, and the chance in favour of survival is doubled by some favourable variation, the effect will amount only to this, that the chances are not a hundred to one but only fifty to one against the favoured individual. Moreover, even when an individual possessing some favourable variation does survive, it will be prevented from becoming the ancestor of a new species or race by the fact that, among the higher animals, every one which is born has two parents, while, by the hypothesis, the favourable variation is found in only one; and as the offspring are, on the average, of intermediate character between the two parents, the favourable variation will be transmitted to the offspring in only half its original force; and to their offspring again, with only one-half of this, or one-fourth of its original force — and so on, constantly

[1] In the *North British Review*, June, 1867.

weakening. It is true that this action will be counteracted by the effect of fresh variations and fresh natural selection; but it can be only under very favourable circumstances, if ever, that the effect of natural selection, accumulating through successive generations, can overcome the weakening of the original tendency through the crossing of the breed. The case will be quite different if a considerable number of individuals present the same variation at once; for the law of probabilities, which shows that the chance of the preservation of one favoured individual among a thousand ordinary ones is almost imperceptibly small, shows also that if a thousand possess the same favourable variation among a million of ordinary ones, a considerable number of the favoured ones will survive and give origin to an improved race; somewhat in the same way that superior valour or training will give only a small extra chance to an individual soldier, but, if other advantages are equal on both sides, will give certain victory to an army.

Summary of the difficulty.—These difficulties have been thus concisely summed up:—[1]

"The final establishment of the superior type is dependent at each step upon three accidents. First, the accident of an individual sort or variety better adapted to the surrounding conditions than the then prevailing type; secondly, the accident that this superior animal escapes destruction before it has had time to transmit its qualities; and thirdly, the accident that it breeds with another specimen good enough not to neutralize the superior qualities of its mate."

Darwin's admission of this.—Darwin, in the latest edition of his *Origin of Species*, admits the force of Prof. Tait's argument in the following words:—"Until reading an able and valuable article in the *North British Review* (June, 1867), I did

[1] From a paper in *Nature* of December 16, 1869, by H., on "Darwinism and National Life."

not appreciate how rarely single variations, whether slight or strongly marked, could be perpetuated. The author takes the case of a pair of animals, producing during their lifetime two hundred offspring, of which, from various causes of destruction, only two on an average survive to procreate their kind. This is rather an extreme estimate for most of the higher animals, but by no means so for many of the lower organisms. He then shows that if a single individual were born, which varied in some manner giving it twice as good a chance of life as that of the other individuals, yet the chances would be strongly against its survival. Supposing it to survive and to breed, and that half its young inherited the favourable variation, still, as the reviewer goes on to show, the young would have only a slightly better chance of surviving and breeding; and this chance would go on decreasing in the succeeding generations. The justice of these remarks cannot I think be disputed. If, for instance, a bird of some kind could procure its food more easily by having its beak curved, and if one were born with its beak strongly curved, and which consequently flourished, nevertheless there would be a very poor chance of this one individual perpetuating its kind to the exclusion of the common form; but there can hardly be a doubt, judging by what we see taking place under domestication, that this result would follow from the preservation during many generations of a large number of individuals with more or less strongly curved beaks, and from the destruction of a still larger number with the straightest beaks." [1]

Fortuitous Destruction: Natural Selection acts less efficiently than Artificial.—Darwin here seems to admit that natural selection will not act so efficiently as the selection which is effected under domestication; and in another passage he says that a "great amount of fortuitous destruction" takes place, especially among young animals, without relation to their greater or less fitness for their life. It is certain, for instance, that

[1] *Origin of Species*, p. 71.

nature will, on the average and in the long run, select the most strongly flying hawks; but no power of flight waiting for development in a nestling hawk will save it from being devoured by a polecat. The more carefully tended domestic races live under quite different conditions from these, and are subjected to an artificial selection that acts with approximately perfect efficiency. Even among them, Darwin insists that selection can do little unless it has a large number of individuals to act on, so as to give chances enough of favourable variation; but when a variation occurs which is decidedly advantageous—not to the organism itself but to its human owner—it is tolerably certain to be selected and preserved. Under the state of nature it is otherwise;—a large number of individuals is there required not only to afford the necessary chances of variation, but to eliminate the effect of "fortuitous destruction," and to change the small extra chance of preservation enjoyed by any favoured individual, into the certainty of the average result in favour of the survival of a favoured race.

Selection can combine Characters.—Thus, the improved breeds of domestic animals have in general (though there are a few remarkable exceptions)[1] not originated in single variations, but by the selection and union, during successive generations, of individuals possessing the required character in the highest degree. Characters derived from different ancestors are combined in them. Most such races have several points of excellence, and these several characters are, or may be, inherited from different ancestors, which were selected on account of favourable variations in those characters alone. Darwin, in speaking of selection by man's agency, insists on the fact that breeders endeavour to obtain single points of excellence at a time; "some chiefly attending to one point, another to another point,"[2] and he maintains that nature's method is similar to

[1] See especially the cases of the Mauchamp sheep (p. 162), the Otter sheep (p. 162), and the Niata cattle (p. 163).

[2] *Variation under Domestication*, vol. ii. p. 222.

this;—species have arisen, not by single acts of variation, but by the slow average result of selection, preserving individuals with advantageous variations, and the union by inheritance of different advantageous characters which have appeared as variations in different individuals. He says:—"The process is like that which I have called unconscious selection by man, and of which I have given several instances. In one country the inhabitants value a fleet or light dog or horse, and in another country a heavier and more powerful one; in neither country is there any selection of the individual animals with lighter or stronger bodies or limbs; nevertheless after a considerable lapse of time the individuals are found to have been modified in the desired manner almost uniformly, though differently in each country."[1]

I do not deny that much may be explained in this way, but I maintain that there are large classes of facts, and those the most important, which cannot be thus accounted for. We shall have to consider these farther on in some degree of detail, and shall now go on with the general question of the sufficiency of natural selection to do all that Darwin ascribes to it.

Will Natural Selection account for Organic Progress?—It appears certain that there has been a tendency to progress in the organic world. If the theory of evolution is true, there has been vast, though not constant, progress in living beings, from *amœba* and other masses of structureless though living jelly, up to Man. Now, even if natural selection among unguided variations could account for the origin of a highly organised being at all, we have still to account for the general tendency of the more highly organised, when produced, to establish themselves, and, when there is not room for both, to supersede the less highly organised.

It will be seen that the questions are distinct. We ask, first—Is it possible for natural selection, acting under the

[1] *Nature*, 2nd November, 1876.

most favourable circumstances, to produce the highest organisms out of the lowest ones by successive improvements? And secondly—Is natural selection a sufficient explanation of the general tendency of the highest races, *when produced*, to survive and extend? We are at present concerned only with the second question.

Darwinian reply, that the highest Organisms prevail by reason of their Efficiency.—To Darwinians the answer will appear perfectly easy. The more highly organised is any being, the better it will be able in general to contend in the struggle of existence; it will have stronger muscles, acuter senses, and subtler instincts; all or any of these will give it an advantage, and will thus increase the chance of transmitting its improved organisation to its offspring.

This answer is true, no doubt, so far as it goes, but it leaves some important factors out of consideration.

This answer overlooks the fact that the Lower Organisms, though Inferior in Power, are Superior in Endurance.—In the first place, though the higher organisms have the advantage over the lower ones in respect of power, the lower organisms have the advantage in respect of endurance. Though a mammal, for instance, is a higher being than a crocodile or a lizard, and is in general superior to it in muscular, nervous, and mental power, and will so far have the advantage in the struggle for food; yet these advantages will be balanced by the greater power of the crocodile or the lizard to bear the want of food.

Also, the Lowest Organisms are the most Prolific.—In the second place, the lowest organisms are the most prolific; and this, obviously, must tend to multiply the chances in favour of a race surviving and spreading. I am aware that Darwin thinks, and on such a question there is no higher authority, that the greater or less degree of prolificness is one of the least important of all factors in estimating the chances of the

survival or extinction of a race. Nevertheless, it must be a factor of sensible magnitude; and these two facts, that the lower races are most enduring and the most prolific, appear to show that organic progress must have some other cause than mere natural selection, and must be due to a vital tendency.

A variation may be injurious if not accompanied by other variations.—There is yet another difficulty as regards natural selection:—I mean as to the sufficiency of the slow process of change by natural selection to adapt the parts of an organism to each other. The subject of highly complex adaptations, such as those of the eye and ear, is to be discussed in a future chapter; but we may now consider those simple correlations of variation which occur in domestic races. These, as we have seen, are not always perfect; thus, when the beak of a special breed of pigeon is enlarged, the tongue is enlarged also, but not in proportion.[1] There must be a vast number of cases where one modification, whether functionally produced or spontaneous, will be not only useless but injurious unless other modifications are combined with it. As an instance it may be mentioned that among the civilized races of men, the habits of feeding make less demand on the strength of the jaws than in the barbarous state, for which reason the jaws have grown shorter; and this change appears to be still in progress. There is thus less room for the teeth to develop; and yet the number of teeth continues unchanged. This is a prevalent cause of diseases of the teeth; for crowded teeth are liable to be irregular, and irregular teeth are more liable to decay than regular ones. Were a wild race, from some change in its habitual food, to become specially liable to diseases of the teeth, it is probable that a race so weighted in the struggle for existence would be defeated and would perish, unless a number of individuals sufficient to give origin to a new race were to vary in the direction of fewer or smaller teeth. Such a race would no doubt be preserved by

[1] See p. 174.

natural selection. But the teeth are not a very variable character, and the change in food that caused the jaws to shorten would not necessarily have any tendency to diminish the number of the teeth; so that the race might not improbably perish before the necessary variation was established.

Perhaps the reply will be, that many races have probably perished from causes somewhat like these; and that only under favourable circumstances can a new variety be formed and established. I do not deny the relevancy of this answer, and I do not urge the above-stated objection as conclusive against the Darwinian theory; I only urge it as one of a mass of difficulties, all tending to make that theory improbable.

Retrogression in consequence of Early Propagation.—Moreover, there must be among living races generally a tendency to retrogression, in consequence of individuals occasionally attaining to sexual maturity at an unusually early age. Most organisms are in constant danger of destruction, so that those which attain earliest to the age for propagation will have the best chance of leaving offspring, and this character will consequently be preserved by natural selection; yet the race so preserved will be an inferior race, because if an organism propagates while yet immature the immature character will be transmitted to the offspring. The possibility of such a case is shown by the instance of the Axolotl, a Batrachian species which propagates while in the tadpole or larva state;[1] and the same is said to be true of a species of Triton or Newt, as well as of the male Salmon.[2] We do not know what retrogressions may have occurred in this way; but the fact that progress has been the rule and retrogression the exception, shows that this tendency to

[1] The mature form of the Axolotl is called the Amblystoma. For a long time the Amblystoma was not known to propagate at all, but the fact of its propagation has been stated by M. Blanchard to the Paris Academy of Sciences. See *Nature*, April 6, 1876.

[2] *Variation under Domestication*, vol. ii. p. 384. The authority of Filippi and Dumeril is given for the statement as to the Triton and the Siredon.

retrogression must be on the whole overpowered by opposing tendencies.

Objection to Darwinism, that the most Variable Groups are not the most Progressive.—Another difficulty of the Darwinian theory, considered as a complete theory of organic progress, is that if all progress were due to natural selection among small unguided variations, the most variable groups ought to be those in which there is most evidence of recent progress. This, however, is by no means the case. The shells of the Foraminifera—microscopic marine organisms almost at the very bottom of the animal scale —are so variable in form, and present so many gradations connecting unlike forms, that no distinct species can be made out;[1] and the Algæ, which are one of the lowest and simplest vegetable classes, are also highly variable; yet the great variability of these classes has not led to any visible progress in organization. If this argument is worth anything, it is of especial force as regards the Foraminifera, which have remained unchanged throughout immensely long geological periods.

If natural selection fails to account for organic progress, it fails even more conspicuously to account for organic variety. We shall have to consider this subject in the following chapters.

[1] See Carpenter on the Foraminifera, published by the Ray Society.

CHAPTER XIII.

CLASSIFICATION AND PARALLEL VARIATION.

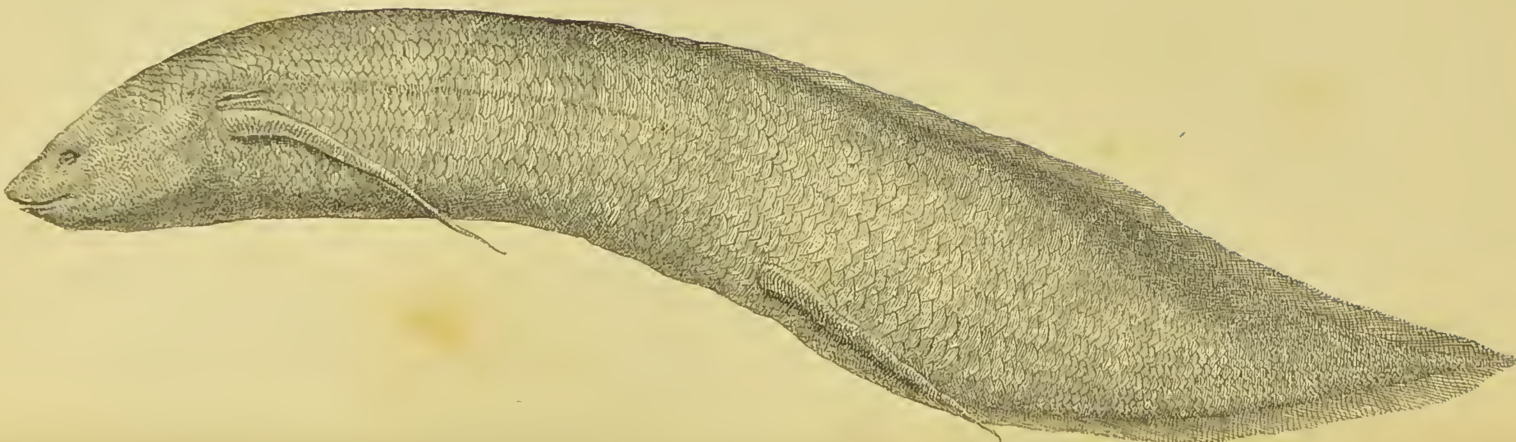
BEFORE we go any further, it is necessary to consider some of the facts and principles of organic classification.

Classification is concerned not with Names but with Realities. Whales and Cirrhipedes.—If any one objects to such an expression as *the facts of classification*, on the ground that classification is an affair of names merely, I have only to say that every one who studies either systematic biology or systematic crystallography soon becomes convinced of the contrary, and learns to see that questions of classification are questions not of names but of realities. Thus, the assertions that the Whale is not a Fish but a Mammal having the external form of a Fish; and that a Cirrhipede (or barnacle) is not a Molluscan but a Crustacean which has put on the form of a Molluscan; are statements concerning not merely the names which naturalists have agreed to use, but the true nature and affinities of those animals.

Questions of Classification which are merely Verbal. Position of Lepidosiren.—There are, however, questions of classification which are little more than verbal. This is the case when two groups, whereof the typical members are very unlike, are nevertheless connected by intermediate forms. Thus, it was formerly an unsettled question whether the *Lepidosiren* ought to be classed as a Fish or a Batrachian,[1] though the former opinion always

[1] The Batrachians are such animals as frogs and newts.

Ceratodus, reduced from Dr. Günther's paper in the *Philosophical Transactions*, 1871.



Lepidosiren annectens. Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast.

preponderated. It is scarcely a metaphor to say that it is a Fish which has been caught in the act of transforming itself into a Batrachian by transforming its swim-bladder into lungs, and preparing to transform its fins into legs. It is now classed as a Fish, partly because of the discovery of the *Ceratodus,* which connects it with the ordinary Fishes; but a new light may any day be thrown on the question, by the discovery of some form connecting the *Lepidosiren* with Batrachians. In the cases above mentioned, on the contrary, any such change in the classification is infinitely improbable, because Mammalia and Fishes, or Crustacea and Mollusca, are not groups that run into each other, any more than a water-dog approximates to a fish; the Whale has no tendency to become a Fish, nor the Fish to become a Whale; and the same is true of the Cirrhipede and the Molluscan.

The Classificatory Value of a Character depends on its being an Index to others. Wings of Insects.—It is little more than an identical proposition to say that the classificatory value of any character depends altogether on the extent to which it is so correlated with other characters as to be an index to the general nature and affinities of the organism. Thus, the presence or absence of wings among Insects is not of first-rate importance in the classification of the genera of Insects, because there are wingless genera in most of the orders which are normally winged. But it is also true, though it may sound like a paradox, that the presence of wings is a very important character of the class of true or hexapod Insects, or rather of its largest sub-class; for there are two orders of true or hexapod Insects, namely the Thysanura (or springtails) and the Collembola, whereof all the genera are wingless;[1] and were a winged genus discovered which unmistakably belonged to one of these orders, it would quite change our ideas of the true affinities

[1] See Sir John Lubbock's admirable work on these orders, published by the Ray Society. The Pediculi or external parasites have no special connection with these, and are generally regarded as degraded forms of Hemiptera, the order to which the Aphis and the Bug belong. Aphis and many other genera of Hemiptera are normally winged.

of that order. This, however, is easily intelligible from the evolutionist point of view:—wings belong to the sub-class of winged Insects as such, but some genera have lost them. This can scarcely be called a hypothesis, for in some families of Beetles the presence of wings is a character that varies between species of the same genus, and even between individuals of the same species. In such cases as these latter, the wings cannot be of much importance to the insect, and it is no exaggeration to say that we are witnessing their disappearance through disuse.

The Differences of Groups began as Variations.—Granting the truth of the doctrine of evolution, the differences which separate species and classes one from the other were, in their origin, variations supervening on the character of the stocks from which they have been derived. In other words, every character which is not common to all organisms whatever must have originated as a variation.

Tree-like form of Classification.—It is obvious that when once the character of any two species or genera have reached that very moderate degree of divergence which suffices to prevent interbreeding, no species of intermediate character can be formed by hybridisation. They may, and generally will, diverge indefinitely with constantly increasing unlikeness; though it is possible that in a few cases there may be convergence of character;—that is to say the descendants may in a few cases become more alike than the progenitors were;[1] but in no case will there be a true reunion—in no case can stocks that have once diverged ever have a common descendant. It follows from this that the true form of classification is that of a tree—a genealogical tree, not complicated by the marriage of relatives. We shall see further on, however, that in the case of groups which are not very remote, this law is most remarkably modified by the existence of transverse affinities.

[1] See p. 161 for an instance of this among swine.

Affinity is distinct from Resemblance: Analogy of Human Kindreds.—Although unlikeness depends on divergence in descent, yet the degree of unlikeness between any two species or classes is not even an approximate measure of the time which has elapsed since their stocks were separated from each other. This is because variation does not go on with any sort of uniformity, but takes place at irregular and generally long intervals; so that one pair of forms may continue with but little change for an indefinitely long time after their separation, while another pair of forms, or one of the pair, may be modified so rapidly, that in a geologically short time their affinity may cease to be recognisable. In a word, the degree of resemblance is not a measure of the true or genetic affinity. Thus the Cirrhipedes are nearly akin to the Crustacea, though in their mature state they do not resemble crustaceans; and if they had lost their metamorphoses, and ceased to pass through their crustacean larva form, their true affinities could scarcely have been suspected. There may be, and probably are, many such cases in the organic world, of real affinity without visible resemblance; and this possibility almost indefinitely increases the difficulty of ascertaining the true classification by descent: just as in human kindreds there is such a thing as family likeness, but the degree of likeness is no measure of the nearness of kindred; brothers are sometimes met with who have no family likeness to each other, and cousins sometimes have more resemblance than brothers. But in human genealogy we have records or tradition, while we have to make out the facts of organic genealogy as we best can, from the resemblances between the various groups, with some help from the facts of geological succession. There is this further parallelism between human and organic genealogy, that in men there are some kinds of characters, such as the form of the features, which are original and not acquired, and are consequently in some degree an index to the man's kindred; while there are others, such as peculiarities of voice and of manner, and to a certain extent complexion, which are much more capable of alteration by the action of

circumstances, and consequently are no index of kindred. Just so, in organic genealogy there are some kinds of characters which are subject to alteration to suit special habits of life, and are thus merely adaptive characters, and are of much less value as indications of the real affinities of the organism than those which are not so alterable.

The Divisions of Classification are generally Dichotomous.—It is not impossible that a stock should produce two or more varieties at once, so as to break up into three or more distinct and unlike stocks; but the probabilities appear to be much against this, because in the state of nature variation and the formation of new species take place only occasionally. It follows that the tree-like branching of classification is generally, perhaps always, dichotomous, that is to say, by divisions into two. We must admit that this can seldom or never be proved in particular cases; but if taken as a postulate, it will generally be found to lead to satisfactory results in classification.

Parallel Variations and Transverse Affinities. Prof. Cope.—The tree-like form of classification is, however, obscured by the fact of analogous or parallel variations. We have seen, in reviewing the varieties of domestic animals and vegetables, that allied species frequently present parallel varieties, so that two varieties belonging to different species may resemble each other very strongly, while yet they are known to belong to distinct species, by the possession of characters which are known to be specific, or else by historical evidence of their origin.[1] Prof. Cope, in a most able and valuable pamphlet on *The Origin of Genera*,[2] has shown that a relation exists between the species of different genera, similar to what we have seen to exist between the varieties of different species; and moreover, that these are not only found here and there throughout the organic world, but exist systematically; so that in many parts

[1] See p. 174 *et seq.*

[2] *Philadelphia*, 1869. Merrihew and Son.

of the system the true form of the classification is not that of divergent groups, but of parallel series, as in the classifications of chemistry. Thus there are what Prof. Cope calls *transverse affinities*; one set of affinities being between different members of the same series, and another set, transverse to these, between the corresponding members of different but parallel series.

The following, for instance, is a possible case :—Let us call three genera A, B, and C, and their species 1, 2, and 3. The affinities of the species will then be thus represented :—

$$\begin{matrix} A^1, & A^2, & A^3, \\ B^1, & B^2, & B^3, \\ C^1, & C^2, & C^3. \end{matrix}$$

The species of the same genus, as A^1, A^2, and A^3, have thus one set of affinities with each other, while the corresponding species of the different genera, as A^1, B^1, and C^1, have another set of affinities, transverse to these. I do not say that instances so complete as that here expressed in symbols often occur, but there are a great number of cases where two species of different genera almost exactly resemble each other in everything except the generic peculiarity. Prof. Cope mentions two very singular instances of these transverse affinities. The first is that of two species of Silurid fishes which resemble each other very closely in everything but a single character of generic importance; but in this they differ :—one of them belongs to a genus which has the distinguishing character of being without eyes. The other instance is that of two species of the order to which the frog belongs, agreeing in the extraordinary habit of carrying their eggs, until they are hatched, on the back, which forms depressions in the skin to receive them; and yet these species belong to different genera. In such a case, shall we conclude that these two species have assumed this peculiarity separately? or shall we conclude that a species in one genus may be descended from a species in another genus, and that all the species of a genus have not necessarily the same origin? Prof. Cope adopts the latter conclusion. He maintains that in a

great number of instances the same species belongs, or has belonged, to different genera; that is to say, the same specific form may put on the characters of various genera, without ceasing to be the same species and to wear the same specific characters. This conclusion is supported by the fact that in many cases the characters of the species appear earlier in the course of development than the characters of the genus;[1] for the characters of longest standing are those which will probably appear first in development.

Reversion and Hybridization.—In such cases as these, the generic characters are more variable than the specific ones. This is supported by the fact, that in many cases of supposed hybridism the hybridization appears to have occurred between species of different genera. "This is so much the case among Cyprinidæ (a family of fishes) that there is scarcely an example of a hybrid between two species of a genus brought forward, but often between species of different genera."[2] The fact of hybridization is very difficult to prove, but Prof. Cope evidently believes that these are not cases of hybridization, but of partial reversion on the part of an individual belonging to one genus, to the character of its ancestor in another genus;—the reversion being only partial, the character produced is intermediate like that of a hybrid. But whether these specimens are reversions or hybrids, they tell equally in favour of Prof. Cope's theory; for either reversion from the character of one species to that of another, or hybridization between two species, will be easier, the more nearly the two are akin by descent; so that these instances, however they may be interpreted, are in favour of the belief that two species having different generic characters may nevertheless be very nearly akin.

[1] "Agassiz says of the development of the North American turtles: 'I do not know a turtle which does not exhibit marked specific peculiarities long before its generic characters are fully developed.' The same can be said of the characters of our salamanders, whose specific marks appear before their generic or even family characters. I suspect this will be found to be a universal law."—*Origin of Genera*, p. 42.

[2] *Ibid.* p. 46.

Argument against Darwin from these Facts.—From these facts, for such they appear to be, of species retaining their specific characters while at the same time they put on the characters of various genera, Prof. Cope infers that organic evolution is guided by no such agency as natural selection among spontaneous variations, but by an innate and inscrutable law of development; for if variation were unguided, it would be infinitely improbable that a species which varies should put on the exact variation, as to both kind and amount, which is needed to transform it into a member of another already existing genus. In other words, if Prof. Cope is right, the several species of a genus may have distinct origins; and the parallel variation of different species required for this appears infinitely improbable, unless there is some unknown cause to guide the variation.

Mivart on "Independent Similarities."—Mivart's argument from "independent similarities of structure" is very similar to Prof. Cope's. In many cases there are organs belonging to different animals which are adapted to the same function, but are in all other respects totally unlike. Such is the case with the wing of the bird and the wing of the insect. Both of these are organs of flight, but they differ in everything else: in form and structure, in position, and in mode of development. The same is to be said of the eyes of insects and those of vertebrate animals, which are as unlike in structure as it is possible for two highly elaborate organs of sight to be. All this is quite consistent with Darwin's theory, and seems to be required by it: for if all organic change and progress begin in spontaneous unguided variations, the law of probabilities appears to require that if two organs are separately produced for the same function, they shall be produced in distinct ways, as the bird's wing and the insect's wing have been. Any close resemblance between two independently produced structures should, on Darwin's principles, be so improbable as to be practically impossible. Yet we do find such "inde-

pendent similarities" in sufficient numbers to be a most serious difficulty, not to say an absolute refutation of Darwin's theory, regarded as a complete theory of the origin of species.

Instances. — Some of Mivart's instances may perhaps be accounted for by natural selection and the effect of similar conditions of life. We shall have more to say on this subject when we come to speak of Mimicry.[1] There is an instance of this kind in the wonderful external likeness between a species of true Mouse and an Antechinus,[2] a small Australian animal belonging to the Marsupial order, of which the Kangaroo is the best known example. This however is an instance of external resemblance only, like that of the Whale to the Fish, and has not necessarily anything to do with anatomical structure; and it seems impossible for truly anatomical resemblances to be accounted for by the conditions of life and natural selection. Yet Mivart says of these:—"So great is the number of similar but apparently independent structures, that we suffer from an *embarras de richesse.* Thus, for example, we have the convoluted windpipe of the Sloth, reminding us of a condition of the windpipe met with in Birds. . . . In Man and the highest Apes the cæcum has a vermiform appendix, as it has also in the Wombat,"[3] (a marsupial animal). We may also mention the points of resemblance between the skeletons of Pterodactyles and those of Birds. Pterodactyles were flying Reptiles, just as Bats are flying Mammals, and any special resemblance between Pterodactyles and Birds must in all probability be an "independent similarity," not due to common descent.[4] The resemblance of the skulls of Whales to those of Ichthyosauri is more remarkable still. Mivart says: "The Whales show striking resemblances to the Ichthyosauria, and this not only in structures readily referable to similarity of habit, but in such matters as greatly elongated premaxillary bones, together with the concealment of certain

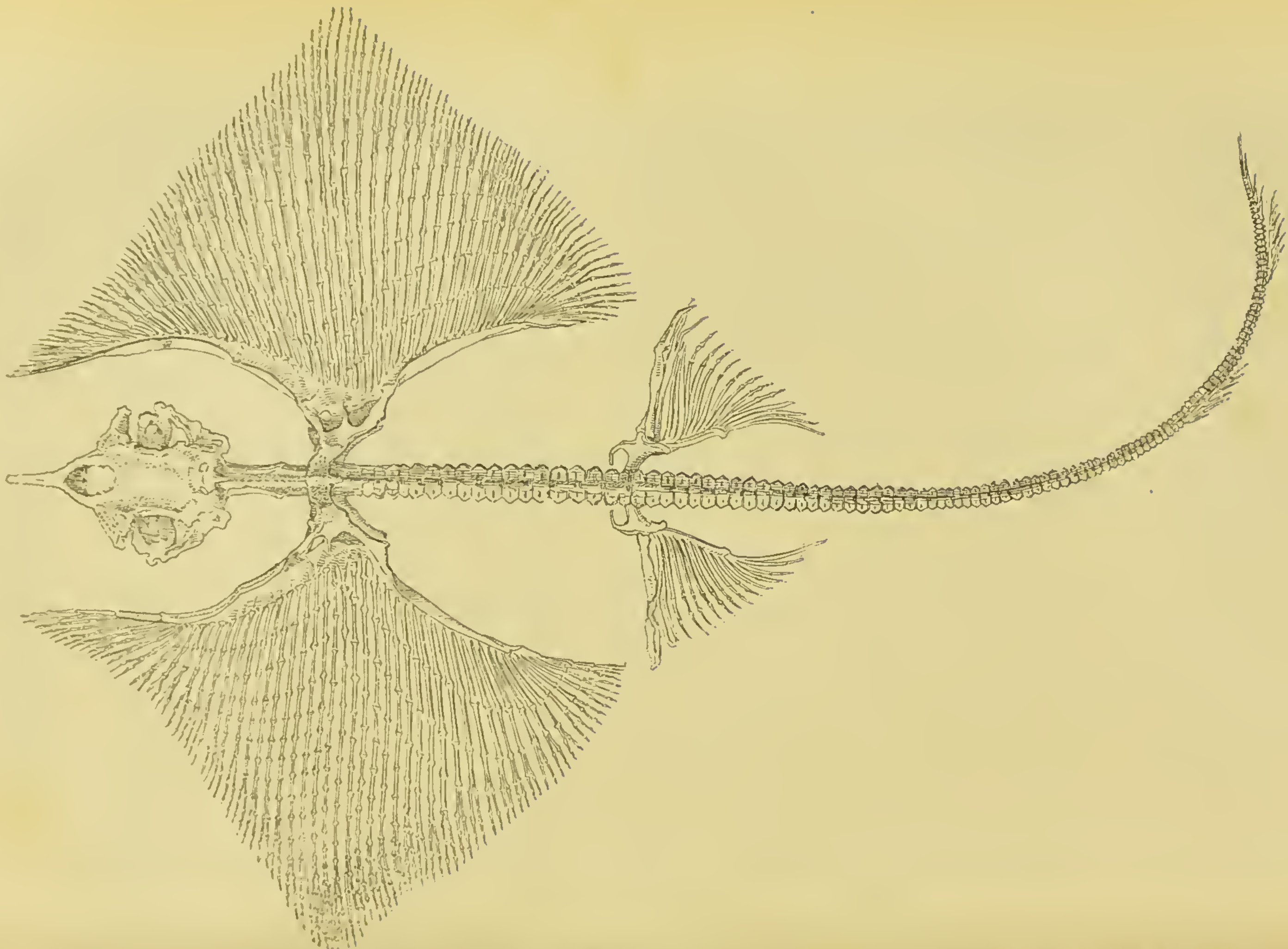
[1] See Chapter XVI.
[2] See the figures of these two animals on p. 93 of Mivart's *Genesis of Species.*
[3] Mivart's *Genesis of Species*, p. 92.
[4] *Ibid.* p. 79.

bones of the skull by other cranial bones." [1] The Ichthyosaurus no doubt lived very much the same kind of life as the Whale, and this may account on Darwin's principles for the similarity in the form of the body, but not, apparently, for such peculiarities as these in the cranial bones.

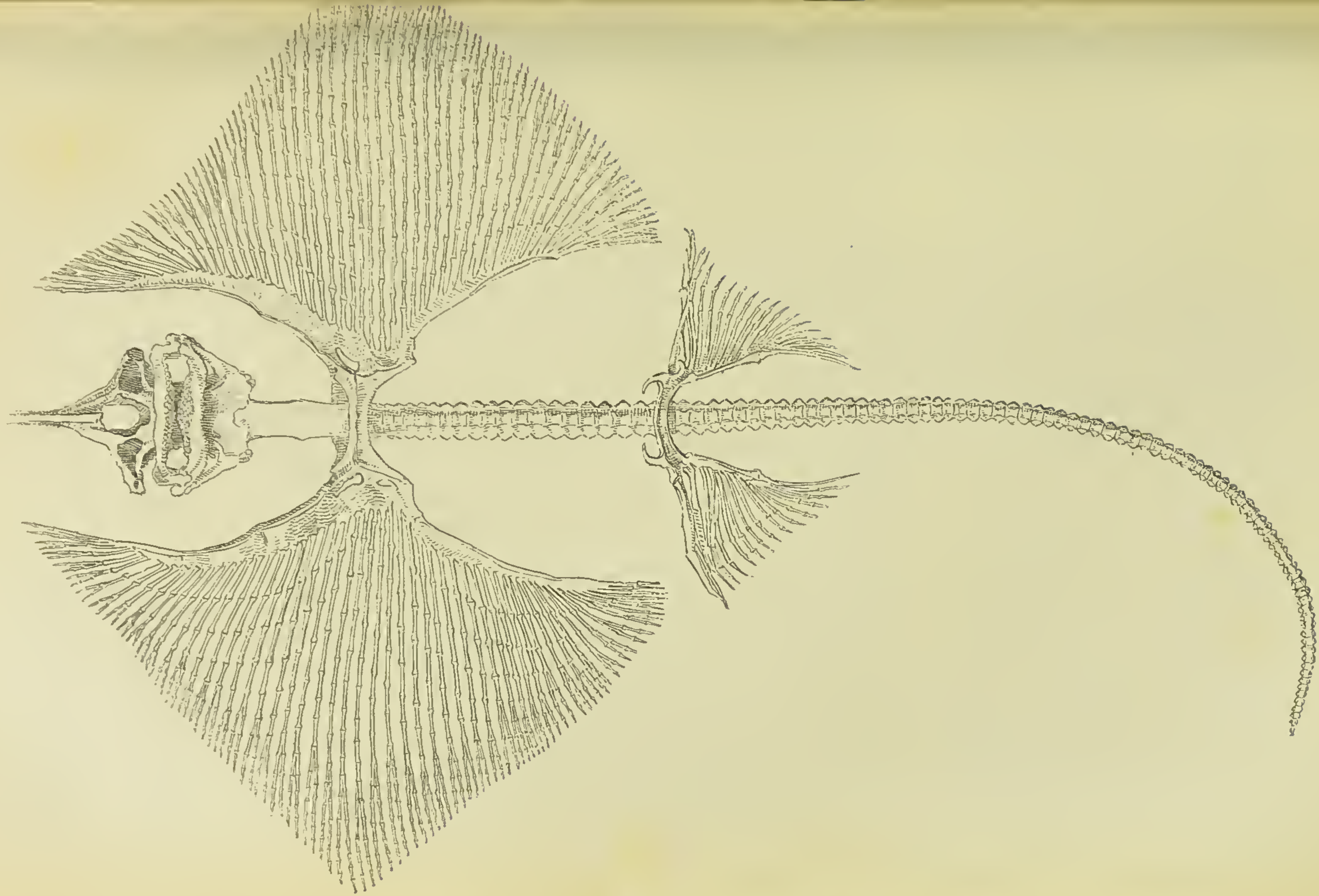
Probable Influence of Correlation.—It seems probable, however, that when certain characters belonging to an order, and needed for its mode of life, are determined by natural selection, other characters became combined with them, in virtue of the unknown laws of the correlation of characters. Thus, when Pterodactyles and Birds separately acquired through natural selection (though I do not admit that this is a complete account of the matter) those characters of the skeleton which are needed for flight, other characters also, respecting which there was no such mechanical requirement, were so modified as to resemble each other in those two classes, through the unknown bond of correlation. And a similar relation exists between the characters of Ichthyosauri and those of Whales.

Teeth-sockets in Mammals and Reptiles.—Another instance of "independent similarity" may be mentioned here. All Mammals, except those few which are without teeth, have their teeth in distinct sockets. The same character exists among Reptiles, but is not universal among them ; it exists only in some orders, and they are orders which have scarcely any other points of special resemblance. It exists in Crocodiles, in Plesiosaurians, in Pterodactyles, in some Dinosaurians, and in a few extinct Lizards; but not in Serpents, nor in Ichthyosaurians, nor in the majority of Lizards.[2] It would appear from these facts that this important character must have originated independently among the Mammalia and among several distinct orders of Reptiles.

[1] Mivart's *Genesis of Species*, p. 88.
[2] See the chapters on Reptiles in Nicholson's *Manual of Zoology*.



Skeleton of Ray or Skate (*Raia*), seen from above. Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast.



Skeleton of Ray or Skate (*Raia*), seen from below. Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast.

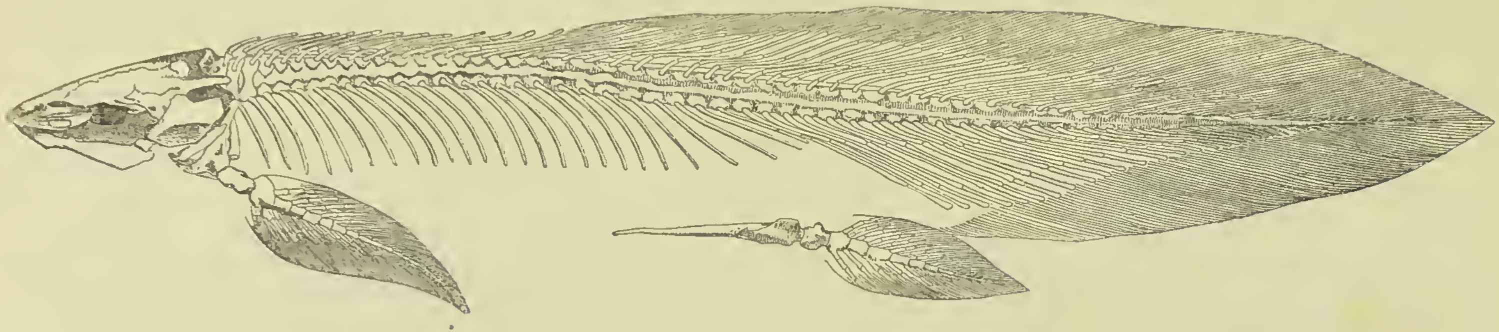
Placental Classification of Mammalia.—The similarities on which the "placental classification" of the Mammalia is founded, are most probably independent similarities. The Hyrax and the Elephant resemble the Carnivora in forming a zonary placenta, and in little or nothing else. It is no doubt difficult to understand why such a character as this should have been separately evolved in different orders; but it is still more difficult to believe that there is any true affinity, beyond that common to all placental mammals, between the Elephant and the Tiger.[1]

Pelvis of the Ray and of the higher Vertebrates.—Another instance of independent similarity is afforded by the resemblance between the pelvis of the Ray and that of the higher vertebrates. The pelvis consists of those bones which come between the spine and the hinder limbs;—in most fishes its two halves are detached like the two sides of an unfinished arch, not being in contact either with each other or with the spine. In all the higher vertebrates the two halves are united to the spine, so as to complete the arch; and in the Ray tribe of fishes also the pelvic arch is complete by the two halves of the pelvis joining each other; but there is this difference, that in the higher vertebrates the pelvis unites with the spine, but in the Rays remains below it. The completion of the pelvic arch however is an interesting approximation in the Ray to the higher vertebrate structure, and it appears to be an independent similarity, because the ascent from the fishes to the higher vertebrates is not through the Elasmobranch order, to which the Ray belongs, but through some form resembling *Ceratodus*, which has the pelvis in the same rudimentary state as most fishes.

Prong-horn Antelope.—A remarkable instance of the same kind is that of the Prong-horn (*Antilocapra*), which, though a true Antelope, has branched horns like a Deer.

Winged Seed-vessels.—Another instance of what must be an

[1] See Prof. Allen Thomson in *Nature* of 25th January, 1872, and Dr. Pye Smith in *Nature* of 2nd June, 1870, and 14th March, 1872.



Skeleton of *Ceratodus*, reduced from Dr. Günther's paper in the *Philosophical Transactions*, 1871.

independent similarity is the fact that the winged seed-vessel, or samara, which is well-known in the ash, the elm, the sycamore, and the maple, is a character, not of entire orders, but of particular genera belonging to distinct orders, in which consequently it must have been separately evolved.[1]

Transverse Affinities.—In quoting from Prof. Cope[2] we saw that there are "transverse affinities" between species belonging to different genera. We have next to mention cases where similarities arising by independent and parallel variations seem to have given rise to systematic "transverse affinities" between forms that stand much wider apart.

Marsupials and Placentals.—The distinction between the Marsupials, of which the Kangaroo is the best known species, and the ordinary or placental mammals, is fundamental, being based on the difference of the entire reproductive system. Yet Prof. Huxley, though leaning more to Darwin's views than to Mivart's, has "called attention to the resemblance between the anterior molars of the placental Dog with those of the marsupial Thylacine. These indeed are strikingly similar, but there are better examples still of this sort of coincidence. It has often, for instance, been remarked that the insectivorous marsupials, *e.g.* Parameles, wonderfully correspond as to the form of certain of the grinding teeth with certain insectivorous placentals, *e.g.* Urotrichus. Again, the saltatory insectivores of Africa (Macroscelides) not only resemble the Kangaroo family in their jumping habits and long hind legs, but also in the structure of their molar teeth; and there is a certain similarity of the upper cutting teeth, or incisors. Now these correspondences [between the teeth of animals very far apart as to their real affinities] are the more striking when we bear in mind that a similar dentition is often put to very different uses [so that such correspondence appears the less needful]. The food of different kinds of apes

[1] Alfred Bennett on Mimicry in Plants, in the *Popular Science Review*, 1872.

[2] See p. 200.

is very different, yet how uniform is their dental structure. Again, who, looking at the teeth of different kinds of bears, would ever suspect that one kind was frugivorous, and another a devourer exclusively of animal food?"[1]

So decided are these transverse affinities, that Prof. Huxley at one time suggested that "the carnivorous, insectivorous, and herbivorous placentals may have been respectively descended from [orders, now in great part extinct, of] carnivorous, insectivorous, and herbivorus marsupials."[2] Had such a derivation of placentals from marsupials really taken place on three distinct lines of descent, it would be a more wonderful case of transverse affinities than any which we can regard as established. It seems however utterly improbable, because the reproductive system, in both animals and plants, appears peculiarly insusceptible of profound modification.

Heterocercal and Homocercal Groups of Ganoid Fishes.—A similar instance is quoted by Prof. Cope from Agassiz. Among the Ganoid order of fishes (a most interesting order, of which the Sturgeon is the best known species) there are a heterocercal and a homocercal group (that is to say, a group with the lobes of the tail-fin unequal, and a group with the lobes equal). This affords a convenient and in some degree a natural classification; but many genera in the different groups "are evidently so nearly allied, that Agassiz, in his *Poissons Fossiles*, has thought it best to arrange the latter together, thus instituting a system transverse, as it were, to the other. This may be necessary, since Kölliker points out transitional forms."[3] It does not appear specially unlikely that the transition from the heterocercal to the homocercal form of tail should have been made on several distinct lines of descent. The converse transition is not probable, because

[1] *Genesis of Species*, p. 77.

[2] *Ibid.* p. 77. Huxley appears to have gone back to the more usual opinion that the distinction between non-placentals and placentals is genetic and fundamental;—in other words, that the stocks are different, and that the change from implacental to placental structure has taken place only once.

[3] *Origin of Genera*, p. 62.

the heterocercal tail is the most like the normal form of a vertebrate tail, and was therefore no doubt earlier evolved than the other.

Prof. Garrod on the Classification of Parrots.—It is probable that when they are systematically sought for, transverse affinities will be found almost every where. Prof. Garrod has endeavoured to work out the subject systematically, as an example, in the single group of the Parrots,[1] a group which has the advantage for the purpose of being well defined and isolated from all others. Classifying the families of the group in four different ways according to four different characters, he finds that no two of these four classifications coincide. The four characters are:—

1. The character of the carotid arteries.
2. The presence or absence of the ambiens muscle.
3. The presence or absence of the furcula (or merrythought).
4. The presence or absence of the oil-gland.

We will first arrange the seven families of parrots (counting the genus Cacatua as a distinct family), according to the character of the carotids, as follows:—

Both carotids present and normal, that is to say, "in the middle line of the front of the neck, side by side and in contact"[2]	Palæornithinæ. Stringopinæ.
Right carotid absent, left normal	Cacatuæ.
Right carotid normal, left running separately along with the left pneumogastric nerve	Arinæ. Pyrrhurinæ. Platycerinæ. Chrysotinæ.

The second character gives a different division, as follows:—

Ambiens muscle present	Arinæ.
Ambiens muscle wanting	Palæornithinæ. Stringopinæ. Pyrrhurinæ. Platycerinæ. Chrysotinæ. Cacatuæ.

[1] In a Lecture on "Evolution and Zoological Formulation," reported in *Nature*, 8th October, 1874. I do not reproduce his formulæ, as I am concerned not with his method, but with his results. His lecture is not written with any special reference to Darwinism.

[2] Prof. Garrod *in loco*.

The third character gives again a different division:—

Furcula present	Palæornithinæ. Arinæ. Pyrrhurinæ. Chrysotinæ. Cacatuæ.
Furcula wanting	Stringopinæ. Platycerinæ.

The presence or absence of the oil-gland is of much less importance than the three preceding characters, so we shall not treat it as co-ordinate with them. But here are three important characters which all give quite different results in classification; they neither coincide, nor form groups subordinate to groups, but produce cross classification, or intersecting divisions. The similarities between the various divisions of the parrot group are, some of them at least, independent similarities, and their affinities are transverse.

Illustration from Family Resemblances.—The difficulty in making out these affinities is the same in kind which there would be if we saw a group of men whom we knew to belong to a few different families, and endeavoured to find out which were brothers by their mutual likeness. Suppose some of the group to be tall and some short; some fair and some dark; some with prominent and some with flat noses; and some with high and some with low foreheads. If the same characters were always combined in the same persons, there would be no difficulty in dividing the group into families; but if these various characters were variously combined in different individuals, so that some of the tall men were fair and some dark, and some of the flat-nosed men had high and some had low foreheads, it would be scarcely possible to make out their kindred by merely observing the points of likeness and unlikeness; and we should be compelled either to give up the attempt, or to change the method, and consider which of the various differences were likely to be indications of kindred, and which were merely personal and accidental.

Probable Character of the First Parrots.—In all probability the first parrots had two normal carotid arteries, an ambiens muscle, and a furcula. These are not now all combined in any known species of parrot, for, strangely enough, those which retain the normal carotids have lost the ambiens muscle. But as these are all characteristic of the class of Birds, they are more likely to have been inherited by Parrots through the first of their tribe from the original stock of Birds than to have been separately evolved. Consequently, the suppression of the right carotid in Cacatua, and the abnormal position of the left carotid in several of the families, are variations from the original character of the Parrots; and the most certain point in the entire classification is that these two variations are independent of each other; that is to say, the suppression of the right carotid in one family and the abnormal position of the left carotid in others are separate variations from the original character of two normal carotids, which is still retained in some of the families. Were all questions of classification as simple as this, the subject would be comparatively free from difficulties.

Primary or earliest Divergence among Parrots, in the Character of the Carotids.—But which of these characters is the most fundamental? Prof. Garrod thinks the most fundamental distinction among Parrots is between those with normal and those with abnormal carotids, "because the conformation [of the latter] is extremely peculiar and unique among Birds, and is therefore less likely to have appeared except as the operation of a specially applied force on a single collection of individuals, the power of transmission being inherited." That is to say, the most fundamental character is that which, when existing in two different groups, is least likely to be a case of independent similarity, and therefore most likely to constitute the primary distinction.

Prof. Garrod's Genetic Classification of Parrots.—The true

genetic classification of Parrots, according to Prof. Garrod, is as follows:—

Position of carotids normal.	Ambiens present; both carotids developed; furcula present			*Not now known to exist.*
	Ambiens absent	Both carotids developed .	Furcula present .	Palæornithinæ.
			Furcula absent .	Stringopinæ.
		Right carotid absent; furcula present		Cacatuæ.
Position of left carotid abnormal.	Ambiens present; furcula present			Arinæ.
	Ambiens absent	Furcula present	Oil-gland present .	Pyrrhurinæ.
			Oil-gland absent .	Chrysotinæ.
		Furcula absent		Platycerinæ.

The above tabular statement will show at a glance that the loss of the ambiens is a variation which must have occurred separately in the normal-carotid and in the abnormal-carotid division of the Parrots; and the same is true of the loss of the furcula.

Transverse Affinities will be found under any Scheme of Classification.—It may be urged in reply, that Prof. Garrod's scheme of classification is only a hypothesis. Granting this to be true, the difficulty of independent but parallel variations is not made by the classification; on the contrary, it will reappear in any possible classification. If the first profound variation that split up the tribe of Parrots into two divisions consisted in the loss of the ambiens muscle, we must infer that the abnormality of the left carotid was a variation that occurred in both of those divisions; and if the first variation consisted in the loss of the furcula, the abnormality of the left carotid and the loss of the ambiens are variations that must have occurred in both of the primary divisions. Indeed, as Prof. Mivart remarks of a similar question, "by no arrangement of branches from a stem can the difficulty be evaded." [1]

It will be observed in the above tabular statement that the Stringopinæ differ from the Palæornithinæ by the absence of the furcula, and the Cacatuæ differ from the same by the absence

[1] *Genesis of Species*, p. 81.

of the right carotid. It appears at present impossible to say whether the Stringopinæ or the Cacatuæ were the first to branch off from the stem of the Palæornithinæ, but the question is not important.

The question of transverse affinities does not arise when the group defined by one character is included within the group defined by another character; as, for instance, winged insects are included among the class of true or hexapod insects, having the characters of six thoracic and no abdominal legs, two antennæ, and respiration by tracheæ. Nor does it arise when two or more characters always co-exist, so that a group may be defined by either of them; as, for instance, the Cyclostome Fishes may be defined among red-blooded vertebrates either by the absence of jaws or by the single nostril; these two negative characters always co-exist, and either of them will define the order. Transverse affinities exist, by definition, when the groups defined by different characters neither coincide nor can be entirely included one within the other.[1]

In the following chapter we shall have to speak of other instances of transverse affinity, quite as wonderful as any here described.

The relative Magnitude of Classes is of no Importance.—Respecting classification, a remark is to be made which is important, though only for the purpose of guarding against an error. The relative magnitude of classes is a matter of no importance whatever. It is natural to one inexperienced in the subject to think, and perhaps systematic naturalists are long before they quite overcome the tendency to act as if they thought, that classes ought not to be considered as of equivalent value unless they bear some sort of proportion to each other as to the number of forms included in each. But this is altogether a misconception.

[1] It would be easier to make subjects of this kind intelligible, if any full and flexible logical terminology were generally accepted for the purpose of describing the various relations of total and partial identity between classes defined by various characters.

It ought not to appear absurd if a class contains but a single species, while another class, side by side with it and of equivalent value, contains thousands. The only questions to be considered in classification are the degrees of fundamental likeness and unlikeness, and the probable order as to time in which divergences of class from class have occurred.

CHAPTER XIV.

CLASSIFICATION AND THE FIXATION OF CHARACTERS.

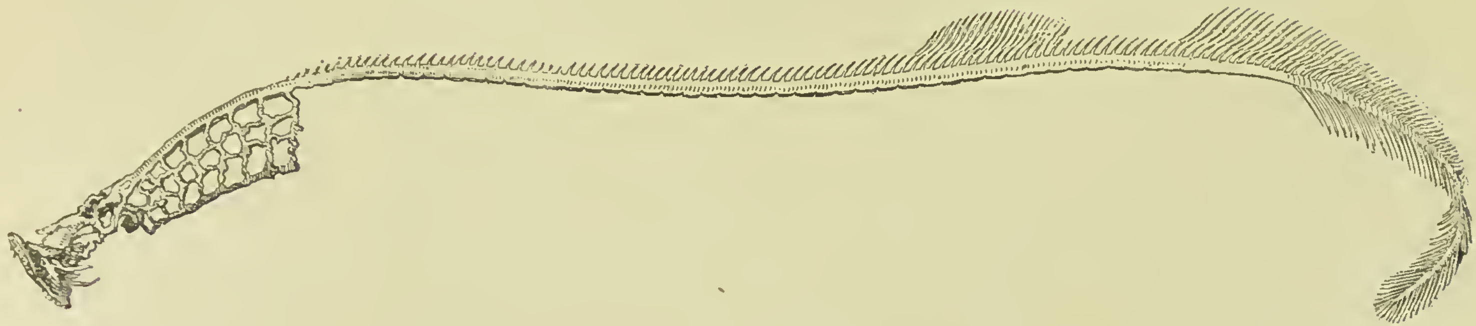
Classification of Vertebrata. Haeckel.—I shall begin this chapter with some remarks on the classification of the Vertebrata.

Haeckel has shown that the old class of Fishes really consists of three distinct classes,[1] more fundamentally distinct from each other than are the higher Fishes from the air-breathing vertebrates. To call Fishes a single class equivalent to Birds or Mammalia, is quite as misleading as to call the Invertebrata a single division of the animal kingdom equivalent to the Vertebrata.

All Vertebrates agree in having at least a rudimentary vertebral column with a spinal cord. The primary division of the group is into those, on the one hand, which have no brain nor skull, no distinct heart, and white blood; and on the other hand, those which have a brain contained in a skull, a distinct heart, and red blood. The former of these contains the single genus *Amphioxus*, which has been usually classed among fishes; the latter includes all the rest of the Vertebrata.

After separating the Amphioxus from the rest, the remaining Vertebrata are divided into those without jaws or limbs, and those with jaws and limbs. (The lateral fins of Fishes, it must

[1] Haeckel would make four, the Dipneusta (*Lepidosiren* and *Ceratodus*—see p. 195) being a fourth; but it seems needless to depart from the usual practice of including these among fishes. The use of the swim-bladder as a lung in this order, is rather an adaptive than a fundamental character; and the peculiar structure of their fins, and the existence of a passage from the back of the nostrils into the mouth, are not important enough to constitute them a distinct class.



Skeleton of Lamprey (*Petromyzon*). Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast. The framework behind the head is a cartilaginous support of the gills, and is not represented in the higher vertebrates.

be observed, are truly limbs).[1] The former of these contains the single group of the so-called Cyclostome or Suctorial Fishes, of which the Lamprey is the best known example; the latter includes the rest of the Fishes, and all the air-breathing Vertebrates. The most fundamental divisions of the Vertebrata may therefore be thus represented:—

White blood, no heart, no brain nor skull	. . . . .	Amphioxus.
Red blood, a heart, a brain in a skull	No jaws nor limbs	Cyclostomes.
	Jaws and limbs .	All other vertebrates.

The Nostrils of Different Vertebrate Classes.—In the Amphioxus no nasal organ has been discovered; it exists in all other Vertebrates. But there is this remarkable distinction, that in the Cyclostomes the nostril is single, while there are two nostrils in every Vertebrate species of a higher grade. This is a most noteworthy fact of classification.

We have to Account for the Fixation as well as the Origin of Characters.—In any theory of the origin of species, we have to account not only for the origin of characters, which indeed is in most cases altogether inscrutable, but also for their fixation. The Darwinian theory admits no cause for this except their utility. If any character arises by spontaneous variation, and is useful to its possessor, it will be preserved by natural selection, and will be fixed by inheritance; that is to say, natural selection will destroy those individuals which do not possess the new character; and inheritance, increasing in strength by successive generations, will tend to prevent reversion to the unimproved state.

The Characters which are the least important Physiologically, are often the most so in Classification.—This no doubt is true, but it

[1] Serpents, some fishes, and a few lizards and batrachians, are without limbs, and yet are really members of this division; they appear to have lost their limbs, which in some cases exist as rudiments under the skin, and in all cases, according to Haeckel, are discernible in the embryo. These limbless vertebrates are thus comparable to the wingless genera among the winged orders of insects. See p. 197.

is very far from explaining all the facts. Were this a full account of the matter, the constancy of any character through wide groups would altogether depend on its functional importance, because natural selection would prevent variation in functionally important characters, at least so long as the organisms continued exposed to the same external influences, while permitting variation in characters of less importance. But such is not the case. On the contrary, the characters of the least physiological importance are often the most constant.

Darwin on this Subject.—"It cannot have been of much importance to the greater number of Mammals, Birds, or Reptiles, whether they were clothed with hair, feathers, or scales; yet hair has been transmitted to almost all Mammals, feathers to all Birds, and scales to all [Lizards and Serpents.] . . . I am inclined to believe morphological distinctions which we consider as important [in classification], such as the arrangement of the leaves, the divisions of the flower or of the ovarium, the position of the ovules, &c., first appeared in many cases as fluctuating variations, which sooner or later became constant through the nature of the organism and the surrounding conditions, but not through natural selection; for as these morphological characters do not affect the welfare of the species, any slight deviations in them could not have been governed or accumulated through this latter agency. It is a strange result which we thus arrive at, namely that characters of slight vital importance to the species are the most important to the systematist."[1]

Classificatory Importance of Rudimentary Organs, and of Flowers and Seed.—It is universally admitted that the importance of a character in classification depends in no degree on its importance to the life of the organism. Organs which have become rudimentary and therefore useless, like the nails under the skin of the Manati (an aquatic mammal), are regarded by the best authorities as of importance at least equal to that of

[1] *Origin of Species*, pp. 175, 176.

organs homologous with them, but in a state of functional perfection and activity. "It may even be given as a general rule, that the less any part of the organization is connected with special habits, the more important it becomes for classification."[1] "With plants, how remarkable it is that the organs of vegetation, on which their whole life depends, are of little signification excepting in [separating the whole vegetable kingdom into] the first main divisions: whereas the organs of reproduction, with their product the seed, are of paramount importance."[2]

Difficulty for the Darwinian Theory about the Fixation of Characters.—These facts constitute a difficulty, which, though by no means obvious, seems to me one of the greatest of all in the way of believing that natural selection can be an approximately complete explanation of the origin of characters.

Conservative effect of Natural Selection.—When a variation is hurtful, the action of natural selection will destroy it. When it is beneficial, the same action will preserve it, and by its preservation for many generations it will tend to be fixed by inheritance, which is a case of the law of habit.

Darwin on Variations which are neither Beneficial nor Injurious.—But when a variation is neither beneficial nor injurious, selection has nothing to act on, and the variety will be perpetuated in its offspring, or will die out, as the case may be, according to the laws of variation and hereditary transmission, without being fixed by selection. Darwin thinks we see in some protean or polymorphic genera "variations which are of no service or disservice to the species, and consequently have not been seized on and rendered definite by natural selection."[3] It is no doubt for this reason that rudimentary organs are specially variable; for rudimentary organs, by the definition of the term, are without any function, and consequently their

[1] *Origin of Species*, p. 365. [2] *Ibid.* p. 365. [3] *Ibid.* p. 35.

variability within moderate limits can be neither useful nor injurious.

Natural Selection will not Account for the Fixation of such Characters.—In the passages just quoted from Darwin, we have the statement of his opinion that characters presenting variations which are neither useful nor injurious are apt to continue especially variable, and that the fixation of such characters cannot be due to natural selection. At the same time it is admitted that, when they become fixed, they are so constant that they are of the utmost importance in classification—for instance, the nature of the dermal covering in animals, and the arrangement of the parts of the flower in plants. Now, through what agency have these characters become so fixed? Darwin only suggests, "through the nature of the organism and the surrounding conditions, *but not through natural selection.*" This appears to be an admission that the theory of natural selection breaks down in the attempt to account for this large and most important class of characters, and that their fixation is as inexplicable as their first appearance.

They appear to be generally Fixed from the First.—He is inclined to think that "in many cases they first appeared as fluctuating variations." I reason chiefly from his facts; but it seems to me that the instances which he has recorded of variations of this kind[1]—that is to say, modifications which are not adaptive—have, in many cases, not been fluctuating, but tolerably constant specific characters from the first; as for instance the origin of the nectarine from the peach,[2] the otter sheep from the common sheep,[3] and the black-shouldered peacock from the common peacock.[4] The abnormal position of the left carotid in some groups of parrots[5] is as good an instance as can be mentioned of a character which is constant throughout an entire group,

[1] See Chapter XI. (The Facts of Variation). [2] See p. 155.
[3] See pp. 153, 162. [4] See p. 170. [5] See p. 212.

which must have arisen suddenly, and cannot have been fixed by natural selection, because it cannot be useful.

Adaptive and Non-adaptive Characters.—Such characters as these, we define as non-adaptive. Adaptive characters are modifications which have supervened on the fundamental plan for the purpose of adapting the species to a particular mode of life. It is impossible to doubt that natural selection has had much to do with their origin; they are indeed the stronghold of that theory. It is probably a prevalent opinion that all characters are adaptive; but this is contradicted by a vast mass of facts. We cannot believe that there is any adaptation to a peculiar mode of life in the abnormality of the left carotid in the above-mentioned Parrots. Almost equally good instances of characters which cannot be adaptive, because they have no relation to any peculiarity in the mode of life, are presented by the various forms of leaves; no such relation will account for the difference between the leaf of the English oak (*Quercus robur*) and that of the evergreen oak (*Quercus ilex*). The same is true of the forms of flowers. No adaptive explanation appears possible of such differences as those between flowers with the calyx below the seed-vessel or above it; separate petals as in the rose, or petals united into a tube as in the harebell: and stamens inserted below the seed-vessel, or in the calyx, or in the petals, or in the style. We may say the same of the different position of the teats in the females of the different orders of the Mammalia.

Three Kinds of Characters.—Considering them in relation to their origin, we distinguish three kinds of characters, though no doubt they graduate into each other, and cannot always be discriminated.

Fundamental Characters—e.g., *Vertebral Column and Spinal Cord: Mode of Growth in Plants.*—The first are what may be called fundamental characters. These are so constant throughout the great divisions of the animal and vegetable kingdoms,

that they appear to be subject to scarcely any variation as to their presence or absence. Perhaps the best instances of these are the vertebral column and spinal cord of the Vertebrata; the beginnings of these are laid down, as a ground-plan, in that lowest of Vertebrates, the Amphioxus; and though in the higher orders they undergo much modification, this is all in the direction of further development—they never disappear or change their position. Few, if any, of the characters that distinguish any other group of equal systematic value with the Vertebrata are so definite as these; but we may also class as fundamental the characters, consisting chiefly in the mode of growth, which separate the vegetable kingdom into the first main divisions, such as the presence or absence of leaves among the Cryptogamia, and endogenous or exogenous growth among the Phanerogamia.

Constancy of such Characters.—It is no merely verbal proposition to say that the characters which are fundamental are also invariable. It is a fact of the highest importance, though its importance is obscured by its familiarity, that the organic kingdoms are divided into great primary groups by characters which are at once invariable within the group and primary in respect of their importance: for nothing can be conceived to be of more importance than the mode of growth in plants, and the outline of the skeleton and of the nervous system in the Vertebrata. It is not, however, surprising that these characters should be remarkable for their constancy; it is difficult to imagine them variable. What are here defined as fundamental characters, are of fundamental importance both in physiology and in classification.

Adaptive Characters—e.g. Fish-like form of some Mammals: in these chiefly is Natural Selection seen.—Adaptive characters stand in contrast with fundamental ones. Familiar as the subject has been made by the works of comparative anatomists, it can never cease to excite a wondering kind of interest to trace

how the ground-plan belonging to the class is preserved through its adaptive modifications, in a far greater degree than utility requires; how the same bones can be traced through the fore-leg of the quadruped, the wing of the Bird and of the Bat, the fin of the Whale, and the hand of the Man. The persistence of the same ground-plan through these modifications shows that they are adaptive, and not fundamental. Perhaps the best of all instances of adaptive modifications are the fish-like forms of the Whale and the Manati, which are true Mammals by every criterion of anatomy and physiology; and the approach to the same in the Seal, which is a Mammal of a distinct order from either of these, and allied to the Dog. Among plants, differences of habit, and such differences as those between herbs and trees, are adaptive, and these are of little value in classification. It is chiefly—I would say exclusively—in adaptive modifications that the effect of natural selection is seen.

Adaptive Characters becoming Fundamental.—It may be maintained that the distinction between fundamental and adaptive characters is only one of degree, and that fundamental characters were adaptive at first; and it may be urged in defence of this view, that characters which are adaptive in a class as regards its relation to other classes, may become fundamental as regards the relation of the subordinate orders of that class between each other. For instance, the Bird's wing is, as regards the entire class of Birds, an adaptive modification of the Reptile's fore-leg; but for the members of the class it has become a fundamental character, and is preserved in an aborted form in the Apteryx, which has rudimentary wing-bones but no external wings.

Characters which are neither Fundamental nor Adaptive, but Classificatory.—This argument might appear nearly conclusive, if all characters which are not fundamental were beyond doubt adaptive modifications of the fundamental plan. But we have seen that such is not the case;—a great number of characters are neither fundamental nor yet adaptive. This is true of

characters of almost all degrees of classificatory importance (which, as we have seen, is quite distinct from functional or physiological importance);[1]—it is true, for instance, of the feathery covering of Birds, which is a character coextensive with the class and found in no other; and, according to Prof. Cope,[2] it is mostly true of the characters which constitute genera; while the characters of species, according to the same authority, are adaptive in a large proportion of cases.

Fundamental, Adaptive, and Classificatory Characters.—We thus find three distinct kinds of characters;—the fundamental, which are of first-rate importance in both physiology and classification; the adaptive, which are of great functional but comparatively small classificatory importance; and a third kind, which we may call classificatory characters, as being of great though not primary importance in classification, but of no great functional importance.

To enumerate all the characters which have importance in classification, while they have little functional importance and therefore cannot be adaptive, would be to enumerate very many of the facts of zoological and most of those of botanical classification. A few have been already mentioned, but it is worth while to mention some others.

Nasal Organs of Vertebrata.—One of these has been touched on in speaking of the classification of the Vertebrata. In all vertebrates higher than the Amphioxus there is a nasal organ. This is perhaps in all orders an organ of smell, and, if so, its usefulness will account for its having been preserved by natural selection. But in the Cyclostomes the nostril is single, while in all higher vertebrates it is double. Now, the division of the original single nostril into two by a septum must be one of very little physiological importance; and therefore if the Darwinian theory were true, such a character, when it once arose by accidental

[1] See p. 220 *et seq.*

[2] *Origin of Genera*, p. 5.

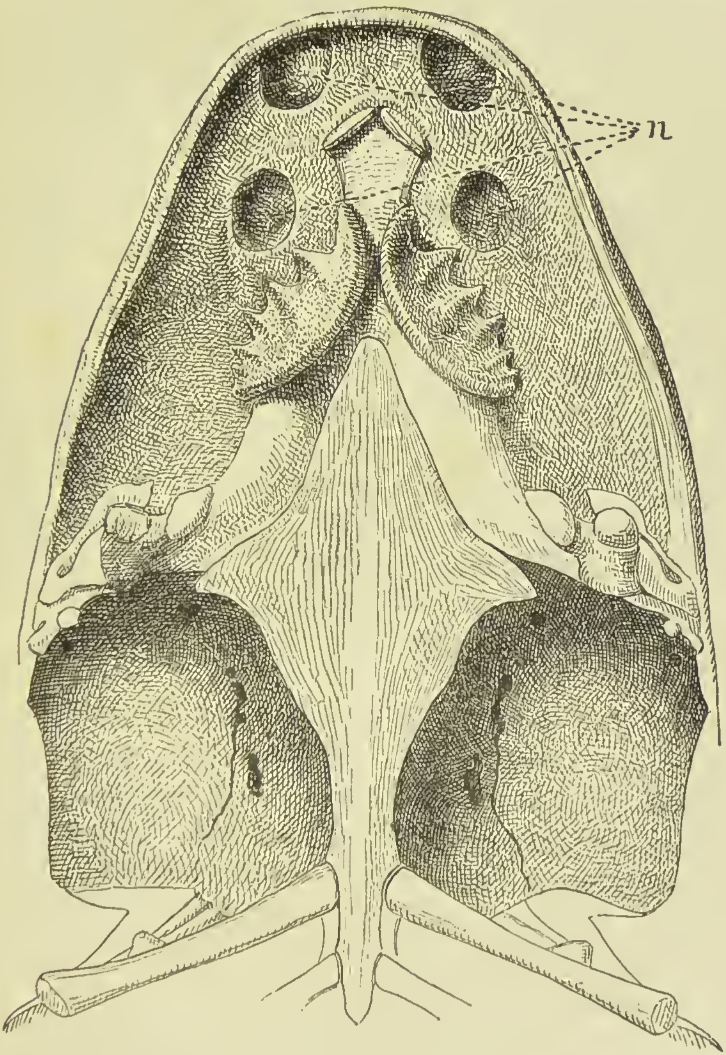
variation, should not have been fixed by natural selection, but should have continued a fluctuating one.

Peculiarities of the Nostrils of the Dipneusta.—Other characters derived from the nostrils are equally remarkable. In the Myxinoids, an order of the Cyclostome class, there is a passage from the back of the nostril into the mouth. In the Lampreys this character disappears, and the nostril is a mere cæcal sac. The same is true of the nostrils of all the ordinary Fishes, till in the ascending scale we come to the Dipneusta, the order which constitutes the transition from Fishes to Batrachians. In these, though the water-breathing organs exist as in other Fishes, the air-bladder is modified to serve as a lung; and the nostrils open at the back into the mouth;—a character which persists among all air-breathing vertebrates. It is no doubt useful to air-breathing vertebrates to be able to breathe through the nostrils, while on the contrary a passage between the nostrils and the mouth would perhaps be injurious to the working of the respiratory mechanism of Fishes; and so far we may explain these characters as due to natural selection. But this explanation will not apply to the passage between the nostril and the mouth in the Myxinoids; and the existence of this character in both the Myxinoids and the Dipneusta—the lowest and the highest of what are usually classed as Fishes—is very remarkable, seeing that any direct connection by descent is utterly improbable.

The nostrils of the Dipneusta have another very strange character—namely, that their anterior openings are within the mouth.[1] In this they differ from all other animals whatever. It is conceivable that this may be of service by keeping minute aquatic insects out of the nostrils, but it can scarcely be compatible with the passage between the back of the nostrils and the mouth being of any use in breathing. It is no doubt possible, and perhaps probable, that when the Dipneusta first

[1] Huxley has endeavoured to explain away the morphological importance of this;—I am not able to judge with what success.

acquired the passage from the back of the nostrils into the mouth, their nostrils were external like those of all other



Upper jaw of *Ceratodus*, seen from below, showing the anterior and posterior orifices of the nostrils. From Dr. Günther's paper in the *Philosophical Transactions*, 1871.
It will be observed that the posterior orifices are comparatively very far forward. This is a Batrachian (frog and newt) character.

vertebrates, and that the internal position of the nostrils is a later acquired character. If so, we must suppose that the

higher air-breathing vertebrates are descended from Dipneusta which had their nostrils in the usual external position. But this does not prevent it from being a most strange anomaly, that the first order of vertebrates in the ascending scale in which the passage exists that enables the nostrils to be of use in aerial respiration, is also the only order where we ever find the nostrils so placed as to defeat that purpose.

The facts of classification altogether appear to be different from what they would be if Darwinism were true, and much more complex.

What Characters are most valuable for Classification.—It is obvious that a very variable character, such as size or colour, affords no sufficiently definite basis of classification; while one which is uniform throughout an entire class obviously affords no basis for classification at all. The characters which are most valuable for classification are those which are not liable to sudden variation as between individuals or nearly allied forms, but present variations as between different groups.

Teeth of Mammalia.—The teeth of the Mammalia afford exceedingly good characters for classification. Their differences are in a great degree adaptive, as is shown by the fact that we can distinguish carnivorous and herbivorous teeth; but they are not altogether so, for, as we have seen,[1] very similar teeth in allied genera are sometimes used for eating very different kinds of food. The necessities of adaptation may account for the differences between the forms of the teeth in different genera and orders, but not for the differences between their numbers. Still less, if possible, can adaptation effected through natural selection account for the Ornithorhyncus having teeth of horn instead of bone; or for the peculiarity of the teeth of the Cape ant-eater or aard-vark (*Orycteropus*), in which "each tooth, though apparently simple, is really composed of a closely-set

[1] See p. 211.

bundle of very fine long cylindrical teeth united together side by side."[1] This extraordinary structure is rendered still more remarkable by its "independent similarity" to a member of a widely different class. "Such a structure exists in no other genus of the Mammalia, but is found in the class of Fishes, namely, in the Skate" (or Ray).[2]

Scales of Fishes.—Some of the best instances of characters which cannot be adaptive, are to be found among the scales of Fishes.

Classification of Fishes.—The class of Fishes, excluding Amphioxus and the Cyclostomes, is divided by well-marked anatomical characters into three orders, or rather sub-classes, namely, the Elasmobranchs, the Ganoids, and the Teleosteans. These appear to be branches of one main stem; but we must also enumerate the Dipneusta, though this order does not appear to be co-ordinate with the first three, but is rather to be regarded as a very much specialised branch of the Ganoids.

Elasmobranchs.—The Elasmobranchs include the Sharks and the Rays, besides some less familiarly known forms. Their gills are pouch-like (whence the name of the order), and have several openings on each side. The skull has no distinct bones, and consists of a mere box formed of cartilaginous substance. The eggs are few and large. "The intestine is extremely short; but to compensate for this, there is a peculiar folding of the mucous membrane, constituting what is known as the spiral valve. The mucous membrane, namely, from the pylorus to the anal aperture, is folded into a spiral reduplication, which winds in close coils round the intestine [interiorly, like the screw of a rifle-barrel]. By this means the absorptive surface of the intestine is enormously increased, and its shortness is compensated for."[3]

[1] Mivart on "Likenesses, or Philosophical Anatomy," *Contemporary Review*, November, 1875.

[2] *Ibid.*

[3] Nicholson's *Zoology*, p. 420.

Teleosteans.—The Teleosteans are by far the most numerous order, and include all the common or so-called bony Fishes. They differ from the Elasmobranchs in all the characters mentioned above. The skull is formed of distinct bones, though soldered together. The gills are not pouch-like, but consist of numerous filaments attached to a series of bony branchial arches. The eggs are small and numerous, and the intestine has no spiral valve.

Ganoids.—The Ganoids are a small order, of which the sturgeon (*Acipenser*) and bony pike (*Lepidosteus*) are the best known genera. They are of character intermediate between the Elasmobranchs and the Teleosteans. They resemble the Teleosteans in the structure of the skull and of the gills, and in the character of the eggs; but many of them have a spiral valve like the Elasmobranchs; and the Ganoids and the Elasmobranchs also resemble each other, and differ from the Teleosteans, in the structure of the heart and of the optic nerves. The intermediate character of the Ganoids between the other orders makes it probable that the first Fishes which were developed out of the Cyclostomes had the general character of this order.

Dipneusta.—The Dipneusta resemble the Ganoids in the characters mentioned above, but, as already mentioned, the swim-bladder is changed into a lung, and the nostrils present characters unlike those of any other animals.

The classification here described is beyond doubt a natural one. We have now to describe the dermal covering of these different orders.

Placoid Scales.—Except in a few genera which are naked, the covering of the Elasmobranchs is "what is called by Agassiz, *placoid.* It consists, namely, of no continuous covering, but of more or less detached grains, tubercles, or spines,

composed of bony matter scattered here and there in the integument. In the case of the Rays, these placoid ossifications often take a very singular shape, consisting of an osseous or cartilaginous disc, from the upper surface of which springs a sharp recurved spine formed of dentine."[1]

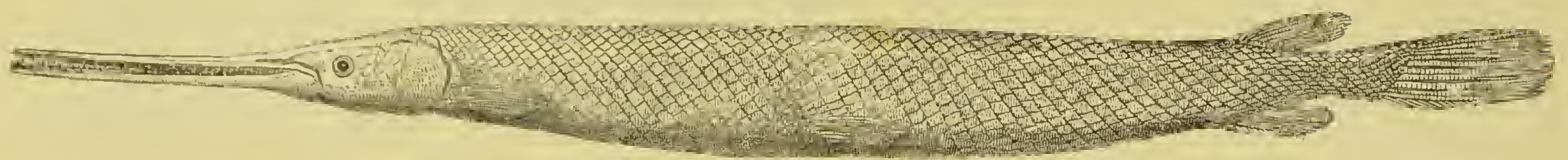
It may be questioned whether natural selection among small spontaneous variations could ever have clothed an originally naked race of fishes with placoid or any other scales; but this case presents no special difficulty, because placoid scales are confined to the Elasmobranch order.

Ganoid Scales.—With few exceptions, the covering of the Ganoid Fishes "consists of scales, plates, or spines. The peculiarities of these scales are that they are composed of two distinct layers,—an inferior layer of bone and a superficial covering of a kind of enamel, somewhat similar to the enamel of the teeth, called ganoine. In form the ganoid scales most generally exhibit themselves as rhomboidal plates, placed edge to edge, without overlapping, in oblique rows, the plates of each row being often articulated to those of the next by distinct processes. In other cases the ganoid structures are simply in the form of detached plates, tubercles, or spines, and in some cases their shape is even indistinguishable from the horny scales of the typical Teleostean Fishes. In all cases, however, whatever their form may be, they have the distinctive ganoid structure, being composed of an inferior layer of true bone, and a superior layer of enamel."[2]

Darwin, as we have seen, appears to admit that such differences as those between placoid and ganoid scales are not to be accounted for by natural selection. But the difficulty of accounting for the peculiarities of dermal covering are immensely increased when we come to the Teleostean order.

Cycloid and Ctenoid Scales.—The Teleostean order is by far the most numerous, and includes all the common or so-called bony

[1] Nicholson's *Zoology*, p. 419. [2] *Ibid.* p. 413.



Spidosteus, or Bony Pike, a fish of the Ganoid order and covered with ganoid scales or plates. Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast.

Fishes. Some of its families are naked, but most are clothed with "cycloid" scales, which, unlike "placoid" and "ganoid" scales, are not bony but horny; they are thin, flexible, and of an approximately circular or elliptical form. In some families the scales are "ctenoid"; these resemble "cycloid" scales, except that they have a comb-like fringe on the side furthest from their insertion in the skin. This is a character which may have appeared as an accidental variation, but it cannot have been fixed by natural selection, because it is a character that could not have given its possessors any advantage in the struggle for existence.

Ganoid Scales in the Teleostean Order: Independent Similarities.—But besides these, some families of the Teleostean sub-class have ganoid plates and scales; and yet they are shown by their anatomy to be true Teleosteans, with no real affinity to the Ganoid order; so that this very remarkable character of ganoid scales, with their double layer of bone and enamel, must have originated separately in the Ganoid order, and in more than two distinct Teleostean families; for the Plectognathi and Lophobranchii at least, though they are Teleostean sub-orders with ganoid covering, do not appear to be near the point where the Teleostean and Ganoid orders diverged, but are, on the contrary, very specialised forms.

Cycloid Scales of Dipneusta.—The last mentioned is one of the most remarkable instances of independent similarity and cross-classification to be met with in the entire organic creation; and there is a parallel and converse fact in the scales of the Dipneusta. The Dipneusta are a sub-order of the Ganoids, to which they belong by the general character of their internal anatomy (for the employment of the swim-bladder as a lung is a physiological and adaptive character); yet they have cycloid scales like the common Teleosteans. This also has every appearance of being an independent similarity; and it is made more strange by the fact that the Dipneusta, in their general character, stand between

the ordinary Ganoids, with their ganoid scales and plates, on the one side, and the naked Batrachian class on the other.

A Classification of Fishes by their Covering would not be natural.—It would be easy and convenient to classify Fishes according to their dermal covering, thus:—

Naked fishes.
Fishes with cycloid scales.
Fishes with ctenoid scales.
Fishes with ganoid scales, plates, or spines.
Fishes with placoid scales.

But such a classification would be altogether artificial; in other words, it would in no degree represent the true or genetic affinities. Nearly all the naked Fishes (excluding Amphioxus and the Cyclostomes, which we do not regard as belonging to the class of Fishes at all), all those with ctenoid scales, and the great majority of those with cycloid scales, belong to the Teleostean order; but the Dipneusta also, though anatomically quite unlike the Teleosteans, have cycloid scales. The Fishes with ganoid covering include almost the entire Ganoid order, and some Teleostean families. Placoid scales are the only one of these characters which is nearly coextensive with a natural order, namely the Elasmobranchs.

Forward Position of the Ventral Fins in some Fishes.—A most remarkable instance of a character which can scarcely be adaptive, and in all probability has arisen suddenly, is presented by the position of the pelvic or ventral fins in some families of Teleostean Fishes. It is admitted by all that the fins of Fishes correspond to the legs of quadrupeds; and in most Fishes the correspondence is nearly perfect in respect of position. If we accept the doctrine of evolution, we cannot doubt that the first fins which were developed on Fishes corresponded in position to the legs of quadrupeds, and that from such Fishes all quadrupeds are descended, as well as all existing Fishes,

not including the finless Amphioxus and Cyclostomes. But there are entire tribes of Fishes which deviate very strangely from this arrangement, having the fins that correspond to the hinder-legs of a quadruped as it were moved forward, and with them the bones that constitute the pelvis, with which they are in immediate connection; so that the skeleton presents the strange spectacle of both pairs of limbs, with their supporting bones, being situated almost close behind the head. Fancy how marvellous this would be thought if it were seen for the first time in a newly-discovered fossil! [1]

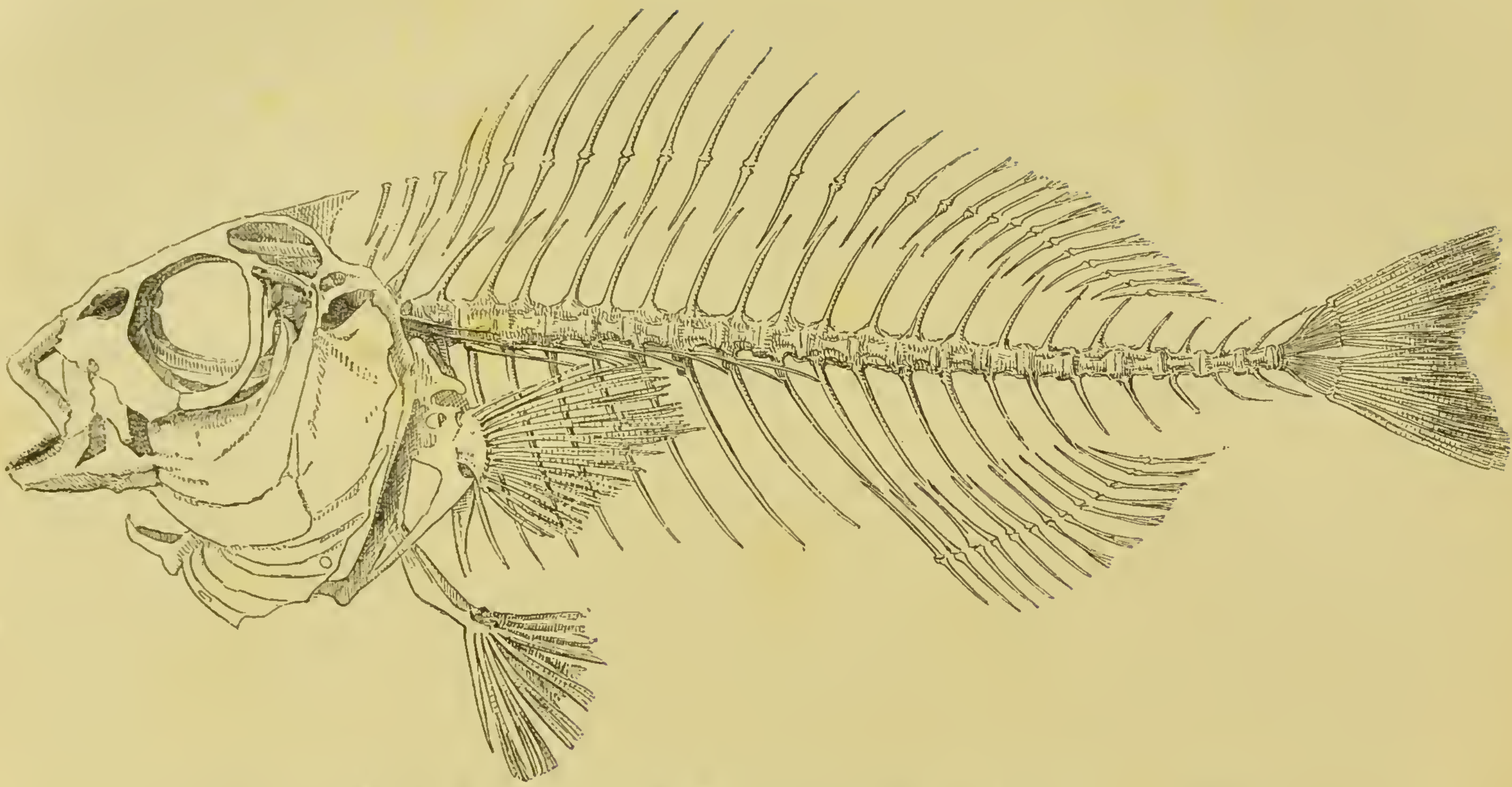
The accompanying illustrations show the skeleton of a Sea Bream, which presents this peculiarity, and that of a Garfish, which is one of the Teleostean Fishes with the fins in the normal position.

This Character must have appeared suddenly.—It appears impossible to doubt that this character must have appeared suddenly. Such an event no doubt seems very strange, but it is still more incredible that the pelvis, with the hinder fins, should have crept gradually forward through ten thousand generations; for there is no reason to think that such a variation would be beneficial, so as to ensure its preservation by natural selection.

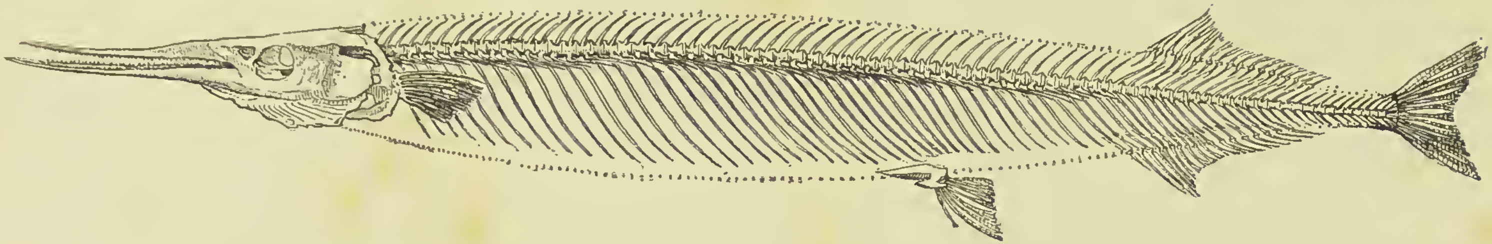
Cross-classification.—This character also constitutes an "independent similarity" between different tribes of Fishes, for it exists among both the Acanthopteri (or thorny-finned Fishes) and the Malacopteri (or soft-finned Fishes), though it is not universal in either; so that it must have originated indepen-

[1] In order to appreciate the marvellousness of this, let us fancy that we first read of it in some scientific periodical in such words as these:—

"The eminent palæontologist, Dr. Digges, has found in the fossiliferous beds of Marvel Valley what may well be called the most wonderful vertebrate yet known. It is unmistakeably a Teleostean fish, but has the pelvis with the pelvic fins (we cannot here say the hinder fins) moved forward, so that they stand immediately behind the head and under the pectoral fins. Dr. Oldlight thinks Dr. Digges's specimen (for only one has yet been found) is a mere individual monstrosity. If this somewhat arbitrary supposition proves untrue, the fish under consideration must be regarded as the type of a new order."



Skeleton of Sea Bream (*Cantharus*). Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast.



Skeleton of Garfish (*Belone*). Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast.

dently in each of those two divisions. It will be seen that this is a case of cross-classification, thus :—

Thorny-finned fishes with ventral fins in the normal position.	Soft-finned fishes with ventral fins in the normal position.
Thorny-finned fishes with ventral fins carried forward.	Soft-finned fishes with ventral fins carried forward.

So that either the abnormal forward position of the ventral fins, or the divergence between thorny-finned and soft-finned structure, must have occurred on distinct lines of descent; and the best authorities are of opinion that the distinction of fin-structure is the more fundamental of the two, and the more important for classification.

Origin of Non-adaptive Characters.—We have seen [1] that even when a variation is favourable, so that the tendency of natural selection will be to preserve it, the chance is still against the preservation of any particular individual, even though a favoured one; and, therefore, before the character of a race can be changed, a very large number of individuals must be born having one or more of the characters which are afterwards perpetuated in the new race. But in the case of non-adaptive characters, how do we suppose that they come into existence? at one birth or at many? and how are they perpetuated, seeing that natural selection, by the terms of the case, has no effect?

On this subject we have scarcely any information to guide us; certainly none comparable to the great amount of knowledge which Darwin has accumulated respecting the origin of domestic races by selection among small spontaneous variations. Nevertheless a possible mode of origin, not inconsistent with what we know of the laws of variation, may be suggested for non-adaptive characters also. We speak of the origin of characters as belonging to species or wider groups; the first

[1] See p. 185 *et seq.*

origin of a character, in some individual variation, can never be explained. Darwin says:—

Darwin on this subject: Variety of the Guillemot.—"There can be little doubt that the tendency to vary in the same manner has often been so strong that all the individuals of the same species have been similarly modified without the aid of any form of selection: or only a third, fifth, or tenth part of the individuals have been thus affected, of which fact several instances could be given. Thus, Graba estimates that about one-fifth of the guillemots on the Faroe Islands consist of a variety so well marked that it was formerly ranked as a distinct species under the name of *Uria lacrymans*."[1] Darwin truly remarks, in continuation, that "if the variation were beneficial, the original form would soon be supplanted by the modified form, through the survival of the fittest"; and the fact that the ordinary form and the variety coexist may probably be regarded as a proof that the variation is neither beneficial nor injurious.

Delbœuf's Law of the Tendency to Equality in Number between the Original Form and the Variety.—Prof. Delbœuf of Liège, writing not as a naturalist but as a mathematician, has shown that if, in any species, a number of individuals, bearing a ratio not infinitely small to the entire number of births, are in every generation born with any particular variation which is neither beneficial nor injurious to its possessors; and if the effect of the variation is not counteracted by reversion; the proportion of the new variety to the original form will constantly increase, until it approaches indefinitely near to equality.[2] This is easily proved without putting the demonstration into mathematical form.

It must be remembered, that the number of individuals of a species which can exist on the area which it inhabits is strictly limited, and in most cases the area is full; so that a new variety

[1] *Origin of Species*, p. 72.
[2] *Revue Scientifique*, 13 Janvier, 1877.

of a species, in a case like that supposed, can increase only at the expense of the original form, and by replacing it.

Suppose then the tendency to produce the given variation is one-thousandth, or, in other words, that one in every thousand of the offspring of the old form presents the variation, and that the tendency to reversion is no greater than the tendency to variation;—that is to say, only one in every thousand of the offspring of the variety reverts to the original form;—then at the end of every generation the numbers of the original form and the variety will be the same as if one-thousandth of the original form had been transformed into the variety, and one-thousandth of the variety had been transformed back into the original form; and it is obvious that this exchange will be in favour of the numbers of the variety, which will increase till the two are equal. It is thus shown that if a tendency exists in a species to produce any special variety—as in the peach, for instance, to produce the nectarine,[1] or in the common peacock to produce the black-shouldered peacock[2]—that variety is certain to be able to establish itself, provided of course that the variation is not injurious. This may go far to explain the vast amount of comparatively slight variety, without any obvious purpose, which we find throughout nature.

Darwin's Law and Delbœuf's Law.—I think it probable that Delbœuf's law of the tendency of variations to establish themselves will prove to be of equal importance with Darwin's law of natural selection by the survival of the fittest. It must be observed that these two laws apply to different cases. Darwin's law is, briefly, that a variation which gives its possessor an advantage will cause that variety to become dominant. Delbœuf's law is that a variation which is neither beneficial nor injurious will tend to spread until the new variety becomes approximately equal in numbers to the original stock.

[1] See p. 168 [2] See p. 170.

CHAPTER XV.

THE EFFECT OF CHANGE OF CONDITIONS.

General Variability.—In reviewing the facts of variation,[1] we have seen that changed conditions of life act in various ways to produce change in the organism. One of these is to promote general variability, which gives occasion to natural selection by the survival of those variations which are best fitted to the new conditions of life. We need not here say any more on this subject.

Change of Habit from abundant nourishment.—It is scarcely necessary, except for the sake of completeness in the enumeration, to mention such cases as that of the change effected in the habit of plants by culture and the more abundant nourishment which culture brings. These causes have probably had much effect in producing the cultivated varieties of plants from their wild originals.

Functionally produced Modifications. Physiological Evolution.—We go on to the subject of functionally produced modifications. A typical instance of these is the increase not only in the strength but in the bulk of a muscle which is much exercised. Darwin appears to think that in the evolution of the organic world, the effect of direct adaptations like these has not been great. But Darwin is rather a morphologist than a physiologist, and Herbert Spencer has made an ingenious, elaborate, and, as

[1] See Chapter XI.

it seems to me, very promising attempt to show how the various structures and functions of living beings have been, to a great extent, developed by the action, through countless generations, of external forces on the organism, and of the organism itself in response to the external forces.[1]

Definite changes which are not adaptive.—When we have enumerated, as effects of changed conditions, those changes which belong to mere general variability, and those which consist in functionally produced modifications, among which latter may be included the direct effect of abundant nourishment in promoting growth and changing habit;—besides these, there are important classes of variations, that differ by their definiteness from those which belong to general diffused variability, and differ from functionally produced modifications in having no assignable relation to function. Some of them have been mentioned in speaking of geographical variations and variations occurring in particular years;[2] but there are many far more remarkable instances. Thus, according to Dr. Masters:—

"*Ficus stipulata* grown on a wall has small thin leaves, and clings to the surface like a large moss or a miniature ivy. Planted out it forms a shrub with large, coarse, leathery leaves." [3]

Geographical Variation in the Oyster.—The following instance is much more remarkable, and is strictly a case of geographical variation:—

"M. Costa has recorded that young oyster-shells taken from the shores of England and placed in the Mediterranean at once altered their manner of growth, and formed prominent diverging rays like those of the proper Mediterranean oyster." [4]

[1] See his *Principles of Biology*, especially the second volume. I can add nothing to his speculations, and think it better to refer the reader to his work than to present a *résumé* of them.

[2] See pp. 178, 179.

[3] *Popular Science Review*, 1872, p. 253.

[4] *Variation under Domestication*, vol. ii. p. 280.

Similar facts in Crystalline Form.—We cannot believe that this change in the form of the oyster's shell has anything to do with adaptation to a new mode of life. It is much more nearly analogous to the inexplicable changes which are sometimes produced in the forms of crystals by changes in the liquid from which they are formed. Thus, "Beudant has found that common salt crystallizing from pure water forms cubes, but if the water contains a little boracic acid the angles of the cubes are truncated. And the Rev. E. Craig has found that carbonate of copper, crystallizing from a solution containing sulphuric acid, forms hexagonal tabular prisms; but if a little ammonia is added, the form changes to that of a long rectangular prism with secondary planes on the angles. If a little more ammonia is added, several varieties of rhombic octahedra appear; if a little nitric acid is added, the rectangular prism appears again. The changes take place not by the addition of new crystals, but by changing the growth of the original ones." [1]

Fungi.—This kind of variability, or rather changeability, will probably account for many facts in the life of the lowest organisms. There is evidence that the forms of the inferior Fungi are extremely variable; "it is asserted by Fries, that out of a single species of *Thelephora* more than eight genera have been constructed by various authors;" [2] and we can scarcely doubt that the various forms of Fungi which inhabit particular situations are not all really distinct species, but that the same germ will develop into different forms according to the soil on which it falls. "Thus, no *Puccinia* but the *Puccinia rosæ* is found upon rose-bushes, and this is seen nowhere else; *Onygena equina* is said never to be seen but on the hoof of a dead horse: and *Isaria felina* has only been observed upon the dung of cats deposited in humid and obscure situations." [3] We can scarcely believe that the air is full of the germs of distinct species of Fungi, whereof one never vegetates until it falls on the hoof

[1] Dana's *Mineralogy*, vol. i. p. 138.

[2] Carpenter's *Comparative Physiology*, p. 214.

[3] *Ibid.*, p. 214, *note*.

of a dead horse, and another till it falls on cats' dung. It is probable—indeed we may say certain—that among the lower Fungi, as among crystals, the same species assumes different forms according to the medium where the development takes place. Direct evidence of this is not wanting. Mr. Varley, in examining a fungus which often destroys the common house-fly, found that "by immersing the fly in water the mode of growth of the fungus was altered, the heads being no longer produced, and the whole plant becoming long, crooked, and filamentous." [1]

Entozoa.—The power of many of the lower organisms to develop into different forms in different situations is no doubt the explanation of what was formerly the most perplexing question in biological science—I mean the origin of Entozoa, or internal parasites of animals. The germs of these have no doubt come from without, and have been developed, in their new habitat, into different forms from those which they would have assumed elsewhere. This is almost proved by the discovery that some species of Entozoa alternate by metagenesis [2] with animal forms inhabiting the earth and the water.

Schmankevitsch on Artemia salina.—It appears probable, though we cannot positively assert, that, besides the somewhat exceptional cases of Entozoa and Fungi, many specific and generic transformations have been made under influences like these. This view is supported by the observations of Schmankevitsch on the *Artemia salina* or brine-shrimp, a small crustacean, which dwells in salt-pans. With increasing saltness of the water, it "underwent a remarkable change. In 1871 they still had their characteristic form of tail. In 1874 the two

[1] *Zoologist*, 1850, p. 2674.

[2] Metagenesis, a parallel word to metamorphosis, and signifying that two forms produce each other alternately. Thus, to take an instance from a different class, many hydra-like forms produce medusæ, and the medusæ again produce hydra-like forms. We shall have to speak of the nature of this process at the end of Chapter XVII.

lobes of it, as also their bristles, had entirely disappeared. Simultaneously, the gills were enlarged, in correspondence to the smaller proportion of oxygen in very salt water. [This last was a functionally produced modification.] The body as a whole, however, decreased in size, so that the new form corresponded almost exactly to that of *Artemia Mülhausenii*, formerly regarded as a distinct species. This fact was tested experimentally, and the same results were obtained by artificial breeding in salt water of increasing degrees of concentration. Further, by the reverse experiment, the *Artemia Mülhausenii* was, even in a few weeks, altered in the direction of *Artemia salina;* and this last form was, by continued dilution of the salt water, transformed into a *Branchipus; i.e.*, to a genus which, of larger dimensions than *Artemia salina*, has a somewhat different tail, and one abdominal segment more, and which also is propagated sexually, while parthenogenesis is the rule with *Artemia*." [1]

Season Dimorphism. Weisman on Vanessa.—Another fact which shows how species may have originated is that of season dimorphism. Some species present different forms according to the season when they are hatched. Thus, those caterpillars of the butterfly *Vanessa prorsa* which survive the winter come out as *Vanessa levana*, which was formerly supposed to be a distinct species; and Dr. Weisman has found that caterpillars which would naturally have changed into butterflies of the form *prorsa* are made to change into *levana* by keeping them at a temperature a little above freezing. Weisman thinks that the winter or *levana* form must have survived the glacial period, and that the summer or *prorsa* form has been produced since then as the summers grew warmer. He supports this view, which in itself seems probable, by the fact that another butterfly, *Pieris napi*, is dimorphic in the same way, and in Lapland and in the Upper Alps only the winter form is found. *Leptodora hyalina*,

[1] *Nature*, June 8, 1876, p. 133.

one of the lower Crustacea, also presents season dimorphism.[1] It is obvious that one of the two forms of a seasonally dimorphic species might be destroyed by a change in the climate of the country inhabited by the species, or by migration into a different climate; the summer form would disappear, as we see that of *Pieris napi* actually does, in a wintry climate, and the winter form would cease to exist in perpetual summer. If then such a species as the *Vanessa* of which we have been speaking, were exterminated in its native country after sending colonies into warm and into cold regions, the colony in the warm region would exclusively consist of the form *prorsa*, and that in the cold region exclusively of the form *levana*, and no indication would be left that the two had originally been forms of the same species.

Galls.—But the most remarkable and decisive case of changes in character which cannot be due to adaptation is perhaps that presented by the galls which are formed on oaks and other trees by the poison of insects. Darwin quotes Mr. Walsh's statement that "galls afford good, constant, and definite characters; each kind keeping as true to form as does any independent organic being." The character of the galls varies with the species of insect producing them, though the Cecidomyidæ, to which family the insects belong, are so nearly alike that it is scarcely possible to distinguish the adult insects; and it generally, though not always, varies also according to the species of tree.[2] In this morphology, purpose, or adaptation, is out of the question, and the only applicable analogy is that of the modification of crystalline form as an effect of the chemical ingredients of the solution.

[1] See *Nature*, June 17, 1875, p. 127, for these facts. The statement about *Leptodora hyalina* is made on the high authority of Sars.

[2] *Variation under Domestication*, vol. ii. p. 283.

CHAPTER XVI.

MIMICRY, COLOUR, AND SEXUAL SELECTION.

Special explanation needed for these Characters.—The purpose of the present chapter is to consider the probable origin of three of the most peculiar kinds of character to be met with in the organic creation. I do not mean that they are uncommon, but that they need special explanation.

Mimicry.—I speak of mimicry first, though it is a less common and less simple phenomenon than ordinary coloration, because the facts of local variation, with which we have been occupied in the preceding chapter, appear to throw much light on its probable origin.

Mr. Bates on Mimicry among Butterflies.—Most of the cases of mimicry which have been as yet described are among insects. Its purpose appears to be the protection of a naturally defenceless species, by causing it to be mistaken by its enemies for a species which is naturally defended. Thus, insects which sting are never known to mimic others, though others in some cases mimic them.[1] It is not the purpose of this work to describe facts exhaustively, and respecting the facts of mimicry I shall only quote the following:—

Mr. Bates, the author of *The Naturalist on the Amazons*, has shown that "in a district where, for instance, an *Ithomia* abounds in gaudy swarms, another butterfly, namely a *Leptalis*,

[1] Darwin's *Origin of Species*, p. 377.

will often be found mingled in the same flock, so like the *Ithomia* in every shade and stripe of colour, and even in the shape of its wings, that Mr. Bates, with his eyes sharpened by collecting during eleven years, was, though always on his guard, continually deceived. When the mockers and the mocked are caught and compared, they are found to be totally different in essential structure, and to belong not only to distinct genera, but often to distinct families. If this mimicry had occurred in only one or two instances, it might have been passed over as a strange coincidence. But travel a hundred miles, more or less, from a district where one *Leptalis* imitates one *Ithomia,* and a distinct mocker and mocked, equally close in their resemblance, will be found. Altogether no less than ten genera are enumerated, which include species that imitate other butterflies. The mockers and the mocked always inhabit the same region; *we never find an imitator living remote from the form which it counterfeits.*[1] The mockers are almost invariably rare insects; the mocked in almost every case abound in swarms. In the same district in which a species of *Leptalis* closely imitates *Ithomia,* there are sometimes other Lepidoptera mimicking the same *Ithomia;* so that in the same place, species of three genera of moths and even butterflies may be found all closely resembling a species of a fourth genus. It deserves especial notice that many of the mimicking forms of the *Leptalis,* as well as of the mimicked forms, can be shown, by a graduated series, to be merely varieties of the same species; while others are undoubtedly distinct species.

"But why, it may be asked, are certain forms treated as the mimicked, and the others as the mimickers? Mr. Bates satisfactorily answers this question by showing that the form which is imitated keeps the usual dress of the group to which it belongs, while the counterfeiters have changed their dress, and do not resemble their nearest allies." [2]

The *Ithomia* is not preyed on by birds, in consequence of having a disagreeable taste; and to butterflies which have no

[1] The italics are mine.

[2] Darwin's *Origin of Species*, p. 375.

such protection, it is of course a protection to be mistaken for those which have it.

Objection to the Darwinian explanation of such facts from the difficulty of obtaining a first variation.—At first sight, Mimicry appears to be a strong point in favour of Darwinism; the mimicking forms being, according to this theory, produced by the survival, through successive generations, of those individuals belonging to defenceless species which most nearly resembled the species which have natural means of defence. But here a difficulty arises, with which we often meet in questions respecting the origin of characters by natural selection, though seldom in so simple a form as when we have to do with colour and mimicry;—namely, the difficulty of understanding how a first variation is to occur in the required direction. Natural selection can preserve no variation which is not useful to its owner;—according to Darwin's theory, individual variations are slight, and the change of specific characters is a slow process;—and it appears impossible that a slight variation could be of any sensible utility to its owner, by producing sufficient resemblance to another species, so as to ensure its preservation by natural selection.

Explanation in the facts of Geographical Variation.—The solution of the difficulty is almost certainly to be found in the facts of geographical variation. There is a great amount of evidence to show that organisms belonging to totally different orders, but inhabiting the same regions, tend in many cases to be modified alike. An instance of this kind has been mentioned in speaking of the characters which distinguish the forest trees of North America from allied European species;[1] and it is a fact of the same nature, that animals in Persia—mammals, birds, and reptiles—as a rule, have paler colours than the same species in Europe.[2] It appears a satisfactory solution

[1] See p. 177.

[2] This statement is made in Mr. Blanford's *Eastern Persia*.

of the difficulty to suppose that such perfect mimetic resemblance as that of the *Leptalis* to the *Ithomia* was at first a mere similarity of local character, which was, as Darwin would say, "seized on" and perfected by natural selection.

Many local or geographical resemblances are much more decided and remarkable than the peculiarities of North American trees or of Persian animals, mentioned above. Mr. Wallace says of butterflies:—[1]

Wallace on local resemblances among Butterflies.—"In South America we have far more striking cases. For in the three sub-families, Danainæ, Acræniæ, and Heliconiinæ, all of which are specially protected [by a taste or smell which prevents them from being eaten by birds], we find identical tints and patterns reproduced, often in the greatest detail, each peculiar type of coloration being characteristic of distinct geographical subdivisions of the continent. Nine very distinct genera are implicated in these parallel changes—*Lycorea, Ceratinia, Mechanitis, Ithomia,*[2] *Melinæa, Tithorea, Acræa, Heliconius,* and *Eueides*—groups of three or four or even of five of them appearing together in the same livery in one district, while in an adjoining district most or all of them undergo a simultaneous change of coloration or of marking. Thus in the genera *Ithomia, Mechanitis,* and *Heliconius,* and sometimes in *Tithorea,* the species of the Southern Andes (Bolivia and Peru) are characterized by an orange and black livery, while those of the Northern Andes (New Grenada) are almost always orange-yellow and black. . . . The resemblance thus produced between widely different insects is sometimes general, but often so close and minute that only a critical examination of structure can detect the difference between them. Yet this can hardly be true mimicry, because all are alike protected by the nauseous

[1] The following extracts are from Mr. Wallace's address as President of the Biological Section of the British Association, reported in *Nature* of the 7th of September, 1876.

[2] *Ithomia* is the genus which is imitated by *Leptalis*. See p. 249 *et seq.*

secretion which renders them unpalatable to birds. In another series of genera, *Catagramma*, *Callithea*, and *Agrias*, all belonging to the Nymphalidæ, we have the most vivid blue ground with broad bands of orange-crimson or a different tint of blue and purple, exactly reproduced in corresponding but unrelated species occurring in the same locality, yet, as none of these groups are protected [by a nauseous secretion like *Ithomia* and others mentioned above], this can hardly be true mimicry. . . . Yet again, in Tropical America we have species of *Apatura* which, sometimes in both sexes, sometimes in the female only, exactly imitate the peculiar markings of another genus (*Heterochroa*) confined to America. Here, again, neither genus is protected, and the similarity must be due to unknown local causes.

"But it is among islands that we find some of the most striking examples of the influence of locality on colour, generally in the direction of paler but sometimes of darker and more brilliant hues, and often accompanied by an unusual increase in size. Thus, in the Moluccas and New Guinea . . . . the most curious are the Euplæas, which in the larger islands are usually of rich dark colours, while in the small islands of Banda, Ké, and Matabello are at least three species not nearly related to each other (*Euplœa Hoppferi*, *euripon*, and *assimilata*) which are all broadly banded or suffused with white, their allies in the larger islands being all very much darker. Again, in the genus *Diadema*, belonging to a distinct family, three species from the small Aru and Ké islands (*Diadema deois*, *Hewitsonii*, and *polynema*, are all more conspicuously white-marked than their representatives in the larger islands. . . . The Philippine Islands seem to have the peculiarity of developing metallic colours."

Wallace on Local Characters among Birds.—There are similar facts among birds, though not so remarkable. "In the Moluccas and New Guinea alone we have bright red parrots belonging to two distinct families, and which therefore most probably have

been produced or preserved by some common cause. Here too, and in Australia, we have black parrots and pigeons; and it is a most curious and suggestive fact that in another insular sub-region—that of Madagascar and the Mascarene Islands—these colours re-appear in the same two groups."

Origin of Protective Mimicry in Local Similarity.—The most remarkable instances of local resemblance mentioned by Mr. Wallace in the above extracts are between genera of butterflies which are specially protected against their enemies by a nauseous secretion, and between other genera which are not so protected. In neither of these cases is the resemblance beneficial to either genus, and therefore it affords nothing for natural selection to work on. But suppose the unknown influence of locality to give the same external appearance to two species of butterflies or of any other organisms, whereof one has special protection of this or of any other kind, while the other is without it; the resemblance will be useful to the unprotected species, by causing its enemies to mistake it for the protected; and will therefore be preserved and increased by natural selection. It seems impossible to doubt that true or protective mimicry has thus originated.

Mimicry is possible only when the two Species dwell side by side.—It is obvious that true mimicry can exist only where the mimicking and the mimicked species inhabit, or have inhabited, the same district, because then only can it be useful.

Resemblances among Plants are mostly not mimetic.—Few, if any, instances of true or protective mimicry appear to be known in the vegetable kingdom. There are, however, a great number of very decided local resemblances, which appear to be in general more directly referable to the action of similar conditions of life than the facts which we have been describing among animals. An able botanist says:—

Alfred Bennett on the effect of Locality on the Habit of Plants.—"Under peculiar conditions all plants, no matter to what

class they belong, or how remote their relationship, have a tendency to assume a certain resemblance in external features. Plants growing in running water, whether flowering or flowerless, *Ranunculus* or *Myriophyllum, Chara* or *Potamogeton,* have the submerged leaves long and filiform, or else cut into slender divisions. Maritime plants growing within reach of the salt spray are apt to become dwarf and fleshy in their habit; and the same remark applies to those which grow on exposed mountain summits, where they are liable to severe though short droughts during the brief but intense summer."[1]

Resemblances between Plants of different Countries.—There are, however, many instances of resemblance which appear to go farther than can be thus accounted for; and, what is very surprising, the most remarkable of them are between plants inhabiting different regions. The authority just quoted says:—

"The visitors to the *soirées* of the Linnæan Society for the last two years have been attracted by the collections exhibited by Mr. W. Wilson Saunders of so-called mimetic plants, consisting of pairs of species resembling one another in their foliage or habit to so extraordinary a degree, and yet belonging to entirely different orders, that even a good botanist might well be excused for passing them over as identical."[2]

Euphorbia and Stapelia imitating Cactus.—There are scarcely any Cacti in Africa, but the place of *Cactus* is supplied by *Euphorbia,* a genus represented in this country by the Spurges. The resemblance of these Euphorbias to Cacti is so strong that "except when they are in flower, it is difficult to believe that these African Euphorbias are not in reality Cacti: and the resemblance is not merely a general one: particular groups, or even species, of African Euphorbia imitate particular groups

[1] "Mimicry in Plants," by Alfred W. Bennett, *Popular Science Review,* January, 1872.

[2] *Ibid.*

and species of American Cactus in the form and habit of the stem and the arrangement of the spines, so that it is almost impossible to distinguish between them. This singular imitation is not, moreover, confined to these two families. The accompanying illustration, reminding one irresistibly of a familiar *Cactus,* is drawn from a species of *Stapelia,* belonging to the order Asclepiadaceæ, a near ally of the brilliant and fragrant

Rhipsalis Funalis a Cactaceous plant from Tropical America, and *Euphorbia Trincalli* from South Africa. From Alfred Bennett on "Mimicry in Plants," in the *Popular Science Review,* January 1872.

Stephanotis and *Hoya* of our stoves, and equally remote from the Cactaceæ and the Euphorbiaceæ."[1]

Other instances.—I quote a few more instances of imitative habit in plants from the same authority:—

"Kunze, a great authority on ferns, considered the curious *Stangeria paradoxa,* a Cycad, allied to the Conifers, as a true Fern."

[1] "Mimicry in Plants," by Alfred W. Bennett, '*Popular Science Review* January, 1872.

Dr. Berthold Seemann met in the Sandwich Islands with a variety of *Solanum nelsoni* which looks "like *Thomasia solanacca* of New Holland, a well-known Buettneraceous plant

Stapelia assuming the habit of *Cactus*. From Alfred Bennett on "Mimicry in Plants," in the *Popular Science Review* January, 1872.

of our gardens, the resemblance between these two widely-separated plants being quite as striking as that pointed out in Bates's *Naturalist on the Amazon* between a moth and a humming-bird."

"Dr. Hooker describes and draws in his *Flora Antarctica* a most singular species of *Caltha*, allied to our marsh-marigold, whose leaves are almost an exact reproduction of those of *Dionœa muscipula* or 'Venus's fly-trap.' In the collection of Mr. Saunders is a species of olive, *Olea ilicifolia*, and a variety of the common holly, *Ilex aquifolium*, var. *macrocarpum*, in which the resemblance is extraordinarily close, not only in the shape of the leaf and of the spiny teeth, but in the very arrangement of the principal veins, and even in the texture and colour."

Parallel Case among Animals.—These cases may be compared with the resemblance in external appearance which has been mentioned in a previous chapter[1] between the Mouse and the Antechinus, though they belong to distinct orders with widely different anatomy, and are native to different countries. It is, however, most remarkable, that resemblances like these among animals are generally between species inhabiting the same country, whence protective mimicry arises;—while among plants they are generally between plants of different countries.

These Resemblances are of Habit and Dress only.—The resemblances of which we have been speaking in the present chapter are not structural but merely external, consisting in what is called in plants habit, and in insects and shells dress. "In all large natural families of plants there is a more or less distinctly observable habit, or *facies*, easily recognisable by the practised botanist, but not always as easily to be expressed in words. . . . What have been hitherto spoken of as mimetic plants are simply cases where a plant belonging to one family puts on the characteristic habit of the other;"[2] but in this work the term mimicry is confined to cases where resemblance is useful to the mimicker.

[1] See p. 204.

[2] See Professor Thiselton Dyer's paper "On so-called Mimicry in Plants," read at the British Association and reported in *Nature* of the 31st of August, 1871. See also his paper "Homoplastic Agreements in Plants," *Nature*, Oct. 26, 1871.

Alfred Bennett on Structural Resemblances among Plants.—Among plants as well as animals there are, however, many resemblances that go farther than these, and amount to resemblances of structure. "Cases of homoplasy (or resemblance not depending on true affinity) are referable to two distinct classes—resemblances in general habit, and resemblances in particular organs. The former, as in the case of the homoplasy between a *Cactus* and a *Euphorbia* or a *Stapelia*, or between a *Kleinia* and a *Cotyledon*, are no doubt due to the operation of similar external conditions of climate and soil. But in the second class this explanation wholly fails. . . . I have on my mind in particular two 'samaroid' fruits, both from the forests of Brazil, so absolutely identical in external *facies* that distinction is quite impossible without dissection, and yet belonging to exceedingly remote orders. . . . The singular part of this resemblance is, that, so far as we know, it is never protective. In one Bee Orchis (*Ophrys apifera*) we have what might well have been assumed *primâ facie* to be a case of protective (or, rather, beneficial) resemblance, the flower being so fashioned in order to attract bees to assist in its fertilization. It is remarkable, however, that the Bee Orchis is one of the few plants that appear to be perpetually self-fertilized, never being visited by insects."[1]

Special resemblances, like the case mentioned in the foregoing extract, of "samaroid" or winged fruits, like that of the sycamore, belonging to different orders, yet externally indistinguishable, appear quite impossible to account for as a result of similar conditions of life.[2] This appears to be a fact of quite a different class from local resemblance and mimicry;—it is more of the nature of those analogical resemblances which we have seen to exist in the animal kingdom, such as ganoid scales in fishes which do not belong to the Ganoid order,[3] and the forward position of the pelvic bones and fins in families of both the thorny-finned and the soft-finned fishes.[4]

[1] *Nature*, 2nd November, 1871. [2] See p. 210.
[3] See p. 235. [4] See p. 237.

Mansel Weale on true Mimicry among Plants.—The statement made by Mr. Bennett in the above quotation, to the effect that special resemblances between plants are not known to be ever protective, appears to admit of some doubt. Mr. Mansel Weale writes from South Africa:—"Of imitating plants I may mention *Ajuga ophrydis*, the only species of its genus in South Africa, which bears a striking resemblance to an Orchid, as also does *Impatiens capensis*, another solitary species. I mention these especially because they are very striking, although I am not aware that they are specially useful—noting, however, that the latter plant is much frequented by insects, often by similar species to those which frequent *Angræcum* and *Mystacidium*, (orchidaceous) plants affecting similar localities."[1] The visits of insects are beneficial by ensuring fertilization, and it will consequently be beneficial to any species of plant to be habitually mistaken by insects for another species which is attractive to them, as Orchids generally appear to be. This, if it is established, is consequently a case of true mimicry, not protective, but beneficial in another way.

Summary on Mimicry.—We may conclude that resemblances of habit which cannot be due to true affinity, or community of origin, are common in both the animal and vegetable kingdoms. In some cases, especially among animals, they are between species inhabiting the same district; and these appear to be due to some influence of locality. When such resemblance is beneficial to one of the species, it becomes protective mimicry, and natural selection will tend to perfect it. Among plants, resemblances of habit quite as remarkable as these are often found, but are generally between species inhabiting different regions; it appears probable, however, that these are due, at least in many cases, to similarity of climate and other conditions of life. Besides these resemblances of habit and dress, there are many cases of truly structural resemblance which are independent of true affinity, and cannot be due to

[1] *Nature*, 27 April, 1871.

community of origin; and these are some of the most inexplicable of the facts of life.

Protective Colouring among Animals.—The subject of ordinary coloration is much simpler than that of mimicry. Among animals, protective colouring—that is to say, colouring which resembles the surroundings of the animal—is so common as to be in no degree exceptional. It is obvious that such colouring must be a protection to an animal which is liable to be devoured by others, by preventing its enemies from seeing it easily;—thus, a leaf-eating insect will be protected by being of a leaf-green colour. The same principle applies to animals which are not in danger of being devoured, but devour others, because the more inconspicuous they are made by their colour, the more easily they can steal upon their prey. This no doubt is the explanation of the tawny colour of the lion, which lives among deserts, and the whiteness of the polar bear, which lives among ice and snow.

Protective Colouring among Plants.—Such cases are found in the vegetable kingdom, though they appear to be much rarer among vegetables than among animals. "That excellent observer, Dr. Burchell, in his Travels, vol. i., p. 10, remarks:—'On picking up from the stony ground what was supposed a curiously-shaped pebble, it proved to be a plant, and an additional new species of the tribe of Mesembryanthemum, but in colour and appearance bore the closest resemblance to the stones between which it was growing. . . . . A great number of Karoo (or desert) plants have tuberous roots of similar form and colour, and it is especially curious to notice that, among the Asclepiadeæ, many species, such as *Raphionueme*, which are found in the grassy country, have their tubers hidden beneath the soil, while others which occur in the stony Karoo, such as *Brachystelma filiforme*, have them above the soil; and so perfectly do they resemble the stones among which they are found, that when not in leaf it is almost impossible to distin-

guish them.'"[1] Of course the use of protective colouring or form to a plant is to prevent it from being seen and eaten by herbivorous animals.

Such protective resemblance as this amounts to mimicry, though it is mimicry not of other plants, but of inanimate objects. There are similar and even more striking instances of the same kind among animals, such as the following among tropical species of bats:—

Instances among Bats.—"A species of Kerivoula was brought to me by a native. The body of this bat was of an orange-brown, but the wings were painted with orange-yellow and black. It was caught, suspended head downwards, on a cluster of the round fruit of the longan-tree (*Nephelium longanum*). Now this tree is an evergreen, and all the year through some portion of its foliage is undergoing decay; the particular leaves being, in such a stage, partially orange and black. This bat can therefore at all seasons suspend from its branches, and elude its enemies by its resemblance to the leaf of the tree."[2]

"A familiar instance of what appears to be protective mimicry occurs in the species of *Pteropus* (flying-fox). These, the largest of all bats, measuring on an average nearly one foot in length, with an expanse of wing of from four to five feet, are, from their large size, very conspicuous objects, even when the wings are closed, and easily seen from the ground when hanging from lofty trees. With very few exceptions, these bats have the fur of the back of the head and of the nape of the neck and shoulders of a more or less bright reddish or bright buff colour, contrasting strongly with the dark-brown or black fur of the back. At first sight it might appear that this remarkable contrast of colours would render the animal more conspicuous to passing enemies, and consequently more subject to their attacks when hanging in a semi-torpid condition. But any one

[1] Mr. Mansel Weale in *Nature* of 27th April, 1871.

[2] Mr. Swinhoe in the *Proceedings of the Zoological Society*, 1862, p. 357, quoted by Mr. G. E. Dobson in *Nature* of 22nd February, 1877.

who has seen a colony of these bats suspended from the branches of a banyan-tree, or from a silk cotton-tree, must have been struck with their resemblance to large ripe fruits; and this is especially noticeable when they hang in clusters from the leaf-stalks of the cocoa-nut palm, where they may be easily mistaken for a bunch of ripe cocoa-nuts. Hanging close together, each with his head bent forwards on the chest, his body wrapped up in the ample folds of the large wings, and the back turned outwards, the brightly-coloured head and neck are presented to view, and resemble the extremity of a ripe cocoa-nut, with which this animal also closely corresponds in size." [1]

Instances among Insects.—Among insects there are still more remarkable cases. The leaf-insect (*Phyllium siccifolium*) is well known, and specimens are frequently to be seen in entomological collections. Mr. Wallace mentions *Kallima*, a butterfly which, when at rest, can scarcely be distinguished from a leaf, and an insect belonging to the Orthoptera, which can scarcely be distinguished from a dry twig. As in the case of the bats just mentioned, the habits of these insects are such as to make their deceptive appearance useful as a means of protection;—the leaf-like insect rests among leaves, and the twig-like insect lives among branches. Imitation in these cases is carried far beyond the mere likeness of leaves and twigs. Mr. Wallace says of the leaf-like butterfly: "We find representations of leaves in every stage of decay, variously blotched and mildewed and pierced with holes, and in many cases irregularly covered with powdery black dots, gathered into patches and spots, so closely resembling the various kinds of minute fungi that grow on dead leaves, that it is impossible to avoid thinking at first sight that the butterflies themselves had been attacked by real fungi." [2] The same traveller says of one of the twig-like insects: "One of these creatures, obtained by myself in Borneo (*Ceroxylus laceratus*), was covered over with foliaceous excres-

[1] Mr. Dobson, in the letter referred to in the previous note.
[2] Quoted from Wallace in Mivart's *Genesis of Species*, p. 41.

cences of a clear olive-green colour, so as exactly to resemble a stick grown over with a creeping moss or *jungermannia*. The Dyak who brought it to me assured me it was grown over with moss, though alive; and it was only after a most minute examination that I could convince myself it was not so." [1]

Mr. Mivart, in quoting these instances, remarks that "here imitation has attained a development which seems utterly beyond the power of the mere survival of the fittest to produce; . . . . how the first faint beginnings of the imitation of such injuries in the leaf can be developed in the animal into such a complete representation of them." [2] Here again we meet with the difficulty of accounting for a first variation.

Seasonal Coloration. The Ermine.—Another fact of coloration is the well-known and very remarkable one, that some animals change their colour with the seasons, turning white in winter, and putting on a dark colour in the summer. The ermine and the Alpine hare are well-known instances of this. The same is common among birds; it is especially conspicuous among Swimmers and Waders, and also in the Ptarmigan, ~~or snow-bunting,~~ which is allied to the grouse. The animals which put on a coat of white for the winter are benefited by the comparative facility with which a white animal may elude its enemies among the snow; while their summer coat of brown or grey is safer during the seasons when the ground is not covered with snow, because a white animal would be dangerously conspicuous on grass or rocks. This power of changing colour with the seasons, when it is once acquired, is thus certain to be preserved by natural selection. But how is it to be first acquired? In this case, the first variation that we need, in order to account for the fact, has been witnessed. Darwin says: "Many quadrupeds, inhabiting moderately cold regions, though they do not assume a white winter dress, become paler during this season; and this apparently is the

[1] Quoted from Wallace in Mivart's *Genesis of Species*, p. 40.
[2] *Genesis of Species*, p. 41.

direct result of the conditions to which they have long been exposed. Pallas states that in Siberia a change of this nature occurs with the wolf, two species of *Mustela*, the domestic horse, the *Equus hemionus*, the domestic cow, two species of antelopes, the musk-deer, the roe, the elk, and the reindeer. The roe, for instance, has a red summer and a greyish white winter coat; and the latter may perhaps serve as a protection while wandering through the leafless thickets sprinkled with snow and hoar frost."[1] Natural selection cannot cause this in domestic animals. It must be, as Darwin says, the direct effect of the winter climate produced in some unknown way, and is, as he further remarks, a first variation, out of which a change of coat as decided as that of the ermine might be developed by natural selection.

Possible Cause of the Winter Coat.—Francis Darwin compares the winter change in the coats of animals "to the greyness accompanying the impaired nutrition of old age, or to that caused by injuries; *e.g.*, in the hair about old sores on the withers of horses; or, again, to the extraordinary recorded case of temporary greyness of the eyebrow accompanying frontal neuralgia."[2] He might also mention the case of the human beard, where the skin has been shaved a little too closely.

The Chameleon.—But the most wonderful of all the facts of coloration is that some animals, of which the Chameleon is the best known instance, have the power of changing colour almost from moment to moment. This power is of great value to its possessors, because they usually assume a colour resembling that of the surrounding objects, and thus at a little distance become comparatively invisible to the enemies that prey on them. This power must be invaluable to such an animal as the chameleon, which has neither strength nor swiftness, nor any other ordinary means of attaining safety; and once a race of animals was formed with this power, there is not the least doubt

[1] *Descent of Man*, vol. ii. p. 298.

[2] *Nature*, 17th August, 1876.

that it would be preserved and perpetuated by natural selection. But how is it first to be formed? how many generations of animals without this power would have to live and die, before a single individual was born with the slightest tendency to change its colour in correspondence with the colour of surrounding objects?

The power of assuming the Colours of surrounding objects is probably a primary one among Animals.—Were the case of the Chameleon an isolated one, it would be altogether inexplicable. But the same power is possessed by many lizards, to which order the Chameleon belongs; it is common among fishes, and many cuttle-fishes have it in a conspicuous degree. When we connect this with the facts of protective colouring in insects and other animals which have been mentioned, and with the facts of seasonal coloration (though this, as we have seen, may perhaps admit of a different explanation), it appears probable that the power of assuming the colours of surrounding objects is general and primary in the animal kingdom, though of course very unequally developed in different animals, and reaching its climax in the Chameleon. This view is in some degree supported by the following:—

"The experiments of Mr. Leslie on the caterpillars of *Pontia rapæ*, which, when inclosed some in black and others in white boxes, produced chrysales respectively modified to suit the colour of the box (*Science Gossip*, 1867, p. 261), appear to support my view, as also do those of Mr. Robert Holland (*Ibid.* p. 279), in which the coccoons of the Emperor moth spun in white paper were white, while those on soil or in dead grass were brown."[1]

Power of the Chameleon Shrimp to become Transparent.—An extraordinary modification of this power exists in a species of shrimp called *Mysis Chameleon.* An observer says:—"I have

[1] Letter from G. Henslow, in *Nature*, 18th April, 1872.

sometimes bottled live specimens of this little creature while it was of a dark purple colour, and presently after lost sight of it, the fact proving to be, on closer inspection, that it had become almost completely transparent."[1] It is easy to see how such a power as this would be preserved by natural selection, but difficult to guess what its origin can have been. It may be, however, that the power of assuming the colour of the animal's surroundings, supposing this to be a primary power, might vary into the power of losing colour altogether.

But why has not the animal become permanently transparent, like *Salpa*, *Beroe*, and many others among the lower animal classes, though not among the congeners of the *Mysis?* It would appear a much easier and less improbable change to become permanently transparent, than to acquire this extraordinary power of becoming transparent at will, or when frightened. We cannot, perhaps, answer this question with any confidence; but it may be suggested, that as the power of becoming invisible is useful to the individual by enabling it to elude its enemies, so the power of remaining visible is useful to the race by enabling the sexes to recognise each other.

Conspicuous Colouring acquired as a Protection.—In all the cases of protective colouring which we have yet mentioned, the colour is protective by being inconspicuous. This is the general rule, but there are some exceptions, which however are such as rather to confirm than to invalidate the rule. Some animals appear to have acquired bright and conspicuous colours as a protection. In such cases, the animal so coloured is already protected by having some disagreeable smell or taste which prevents it from being eaten by other animals; and when this is the case, conspicuous colouring is an additional protection, by causing it be recognised and avoided by them.[2]

[1] Thomas R. R. Stebbing, in *Nature*, 17th August, 1876.

[2] See Mr. Belt's *Naturalist in Nicaragua* for an account of a frog which is thus doubly protected.

The colouring of Flowers is useful by attracting Insects, which effect cross-fertilization.—One of the most remarkable cases of coloration in the organic world is that presented by the conspicuously beautiful colouring of flowers. This, however, owing to Darwin's researches, is now comparatively well understood. It is scarcely possible to doubt that the use of the bright colouring of flowers is to attract insects which carry pollen from one flower to another, and thus ensure cross-fertilization.[1] Darwin was first led to this conclusion by observing that when any species of plant is fertilized by the wind (as for instance the yew-tree) it never has a brightly coloured flower; and when a species, in addition to open flowers of the usual kind adapted for fertilization by insects, produces "cleistogene," or closed flowers capable of self-fertilization only, these are small and inconspicuous.[2]

Ophrys apifera.—The case of *Ophrys apifera* (the Bee Orchis) is an apparent exception, for, though conspicuous, it is not visited by insects, and appears to be constructed in order to insure self-fertilization. This exception does not confirm the rule, but neither does it contribute anything to its disproof. *Ophrys apifera* most probably inherits its conspicuous flower from an ancestor that was fertilized by insects.

The visual sense of Insects appears to be similar to ours.—This theory of fertilization by the agency of insects appears to imply that insects have similar perception of colour to our own; and this may appear an unwarranted supposition, especially when we remember that the facts of colour-blindness show the sense of colour to be very variable even within the human species. There is, however, some independent evidence to show that, whatever may be their perceptions of colour, the eyes of insects are sensitive to the same rays of light as our own. "The

[1] See p. 146.
[2] See the account of *Vandellia nummularifolia* in Darwin's *Cross and Self-fertilization*, p. 90.

spectrum of the light of the firefly has been examined, and is found to be perfectly continuous, without trace of lines either bright or dark. It extends from about the line C in the scarlet to F in the blue, and is composed of rays which act powerfully on the eye, but produce little thermal or actinic effect."[1] That is to say, the light of the firefly—the purpose of which, beyond doubt, is to attract the opposite sex—contains exactly those rays which are best suited for the purpose, supposing the eyes of that insect to be sensitive to the same rays as our own.

Acquisition of colouring by Flowers through natural selection.—There is no special difficulty in supposing the colours of flowers to be acquired by natural selection—that is to say, by the survival of those varieties which are most successful in attracting insects, and thus ensuring cross-fertilization, with its advantages in promoting the vigour of the race. The colours of flowers are very variable, and so are those of the green parts of plants, as is shown by the wonderful success attained by gardeners of late years in obtaining varieties with variously coloured and mottled leaves. Such variations are no doubt commoner under culture than under nature, but they are probably not uncommon under nature. Forest-trees are subjected to but little culture, yet the copper-beech is a well-known coloured variety; and ivy leaves, though usually green, are sometimes claret-coloured.[2]

Connexion in Animals of Beauty with the Relation between the Sexes.—By far the most wonderful of the facts of coloration in the organic world are those which Darwin has endeavoured to bring under his law of sexual selection. It is very generally found that ornament and bright colour first appear at sexual maturity; that they are most conspicuous during the pairing season; and that they are more developed in one sex than in the other—generally, though not always, in the male. As Herbert Spencer remarks, there is some profound connexion

[1] From the scientific column of the *Illustrated News*, 2nd April, 1870, p. 362.
[2] Sophocles (*Œdipus at Colonus*, v. 673) calls ivy wine-coloured.

between the sexual relation and the development of beauty. But what is the nature of the connexion?

Darwin's theory of Sexual Selection.—Darwin endeavours to account for all these facts as consequences of sexual selection. That law, or hypothesis, briefly stated, is as follows:—Ornamental colouring and structures have originated—as every other character has, according to Darwin—in mere accidental variations. When these appear in the male and are recognised as beautiful by the female, they make the males which possess such characters attractive to the females, and thereby increase their chance of leaving offspring; and characters of this kind, like all others, tend to become hereditary, and to accumulate through successive generations. It is known that characters which first appear at maturity are generally transmitted only to the sex in which they have appeared; and characters which do not appear at an early age generally appear at about the same age in the offspring. According to the theory of sexual selection, beauty and ornament are developed in the male rather than in the female, because the female, being of weaker passions than the male, exerts a power of choice which the male does not, consequently when characters which have no purpose except beauty appear in the males of a species, they are selected by the females and preserved by inheritance, while the converse does not occur.

Wallace's denial of it.—Much is to be said for this theory, as for everything that Darwin has ever propounded. But we must observe that its claims on our acceptance are not to be compared with those of his theory of natural selection. Opinions differ, and will continue to differ, as to how much natural selection will account for; but no one who is competent to form an opinion at all can doubt that it is a really operative cause. With respect to the theory of sexual selection it is quite otherwise; it depends on assumptions respecting the mental nature of animals which are extremely difficult to

verify; and the entire theory is denied by Mr. Wallace, the eminent naturalist who has explored the Malay Archipelago, who ranks with Darwin himself as an observer and collector of facts, and who thought out the outline of the theory of natural selection independently, before the publication of Darwin's great work on that subject. He thinks that the development of colour and ornament at the pairing season is merely a consequence of the increased intensity of life at that time.[1] I do not presume to decide between two such authorities as Darwin and Wallace, but go on to mention a few of the more remarkable of the facts.

Luminous Insects.—It is obvious that in most cases conspicuous colouring must be dangerous, by making an animal visible to its enemies; and, inasmuch as it is certain that any variety or species which is at a disadvantage as compared with others will be extirpated, it appears at first sight incredible that the disadvantage entailed by bright colour in the struggle for existence should be outweighed by any advantage conferred by the same in the chance of leaving offspring. This objection, however, appears to be answered, as to the question of fact, by the case of the glow-worm and other luminous insects. Their luminousness must expose them to be seen and eaten by birds, and the glow-worm, at least, is not protected from them by any disagreeable taste or smell; yet the fact of the species continuing to exist in undiminished numbers proves that this disadvantage must be outweighed by the advantage of the light in enabling the male to find his mate.

Parallel Variation shown in Ornamental Structures.—Ornamental structures, like other structures, exemplify the law of analogous or parallel variations."[2]

Disc form in Feathers: Top-knots.—"The feathers of birds belonging to distinct groups have been modified in almost

[1] See his articles on "Colour in Animals and Plants" in *Macmillan's Magazine*, September and October, 1877.
[2] See p. 174.

exactly the same peculiar manner. The wing-feathers in one of the night-jars are bare along the shaft and terminate in a disc. Feathers of this kind occur in the tail of a mot-mot (*Eumomota superciliaris*), of a king-fisher, finch, humming-bird, parrot, several Indian drongos (*Dicrurus* and *Edolius*, in one of which the disc stands vertically), and in the tail of certain birds of paradise. In these latter birds the feathers, beautifully ocellated, ornament the head, as is likewise the case with some gallinaceous birds. In an Indian bustard, the feathers forming the ear-tufts, which are about four inches in length, also terminate in discs."[1] "Top-knots have appeared in several species"[2] (of domesticated birds).

Difficulty about the fixation of Ornamental Characters.—I now come to what appears to be one of the most formidable difficulties in the way of the theory, at least in the form that Darwin has given to it. He says:—"As any fleeting fashion in dress comes to be admired by man, so with birds: a change of almost any kind in the structure or colouring of the feathers in the male appears to have been admired by the female."[3] We have already remarked that the fixation of characters needs to be accounted for as well as their origin[4]; and were the origin and fixation of ornamental characters due to such an agency as this, they could not fail to be highly variable, instead of presenting nearly the same degrees of fixity and of variability as any other characters. Thus, no birds, except perhaps the birds of paradise, are so conspicuously ornamented as the humming-birds; and Mr. Gould, the great authority on that family, says:—

Mr. Gould on the Characters of Humming-birds.—"It might be thought that four hundred species of birds so diminutive in size, and of one family, could scarcely be distinguished from one another; but any one who studies the subject will soon perceive that such is by no means the case. Even the females, which

[1] Darwin's *Descent of Man*, vol. ii. p. 73. [2] *Ibid.* p. 74.
[3] *Ibid.* p. 74. [4] See Chapter XIV.

assimilate more closely to each other than the males, can be separated with perfect certainty; nay, even a tail-feather will be sufficient for a person well versed in the subject to say to what genus and species the bird from which it has been taken belongs. . . . . In the whole of my experience, with many thousands of humming-birds passing through my hands, I have never observed an instance of any variation which would lead me to suppose that it was the result of a union of two species."[1]

Varieties in Humming-birds.—Mr. Gould mentions some varieties, which, however, give no suggestion of diffused indefinite variability. "In the beautiful genus *Cynanthus*, he tells us that there are some local varieties near Bogota, in which the ornament is partly changing from blue to green; and it is a curious fact that this variation appears to be taking effect under some definite rule or law, inasmuch as only the eight central feathers of the tail are tipped with the new colour. Mr. Gould expressly says of one such variety, from Ecuador, that it possesses characters so distinctive as to entitle it, in his opinion, to the rank of a separate species."[2] The establishment of such a variation as this appears to me much more likely to be referable to Delbœuf's law[3] than to any kind of selective action.

Ornamentation of Humming-birds.—"Different parts of the plumage have been selected in different genera as the principal subject of ornament. In some, it is the feathers of the crown worked into different forms of crest; in some, it is the feathers of the throat, forming gorgets and beards of many shapes and hues; in some, it is a special development of neck plumes, elongated into frills and tippets of extraordinary form and beauty. In a great number of genera the feathers of the tail are the special subjects of decoration, and this on every variety of plan and principle of ornament. In some, the two central

[1] Quoted from the Introduction to Gould's *Trochilidæ*, in the Duke of Argyll's *Reign of Law*, People's Edition, p. 237.

[2] *The Reign of Law*, p. 239.

[3] See p. 241.

feathers are most elongated, the others decreasing in length on either side, so as to give the whole a wedge form. In others, the converse plan is pursued, the two lateral feathers being most developed, so that the whole is forked, after the manner of the common swallow. In others, again, they are radiated, or pointed and sharpened, like thorns. In some genera there is an enormous development of one or two feathers into plumes of enormous length, with flat or spatulose terminations. . . . These differences are often little more than a mere difference of colour. The radiance of the ruby or the topaz in one species is replaced perhaps by the radiance of the emerald or the sapphire in another. . . . . Let me refer to two species of the 'Comets,' in which two different kinds of luminous red or crimson are nearly all that serve to distinguish the species. . . . .

"Where white is introduced into the colouring of the tail feathers, it is not applied to the central feathers, but is confined to the marginal feathers on each side. There is, however, one species, *Urosticte Benjamini*, which affords the only example yet known of a departure from this rule. It is a species in which white is one of the principal ornaments of the bird, and is used in places where it can be placed in conspicuous contrast to the darkest tints. Tufts and lines of purest white shine among the greens and violets of the neck and head, while, in exquisite harmony with this, the four central feathers of the tail are alone dipped, as it were, in a solid glaze of the same white, and the marginal feathers on each side are kept wholly dark."[1]

It appears quite impossible that such perfectly definite and regular differences as these can have originated by the accumulation of slight variations, chosen and selected, as they arose, by the females. They must have originated all at once, by single variations, like the black-shouldered peacock from the common peacock, or the nectarine from the peach.[2] Had they originated gradually, by the selection and preservation of each slight change as it appeared, they could not fail to preserve some trace

[1] *The Reign of Law*, pp. 231, 234. [2] See pp. 168, 170.

of their origin in great indefiniteness and variability; and if it were true, as Darwin thinks, that novelty is prized and selected merely as novelty, ornamental characters like these would never be fixed at all; the most variable races would be the selected ones, and these characters would be as variable as the colours of *Cineraria*, or any other of the most variable florist's flowers.

Equal but unlike beauty in the Sexes. Humming Birds: Parrots.—There are a few cases of both sexes being equally, though differently, ornamented. "Two humming-birds belonging to the genus *Eustephanus*, both beautifully coloured, inhabit the small island of Juan Fernandez, and have always been ranked as specifically distinct. But it has lately been ascertained that the one, which is of a rich chestnut-brown colour, with a golden red head, is the male, whilst the other, which is elegantly variegated with green and white, with a metallic green head, is the female."[1] This is a very unusual case, both sexes being equally ornamented and yet unlike. But there are similar cases among parrots, in one of the species of which the collar of the male is rose-colour, and that of the female emerald green:—in another, the male has a black collar and a pale rose-coloured head, and the female a "yellow demi-collar in front" and a plum-blue head.[2]

Explanation suggested by Darwin.—Darwin suggests as a possible explanation of such cases, but without committing himself to it, that the numerical proportion of the sexes may in former ages have varied, males being at one time in excess and females at another;—the sex which is the most numerous has to compete for mates: and, according to the theory of sexual selection, such competition develops beauty in the sex which has to compete. But we have no reason to think that the numerical proportion of the sexes is a specially variable character. This explanation appears to be of the kind which the

[1] Darwin's *Descent of Man*, vol. ii. p. 220.
[2] *Ibid*, p. 230.

old logicians used to call *ignotum per ignotius*, or at least *difficile per difficilius*.

Reversal of the sexual characters: Birds, Fishes, Insects.—There are among birds a few other curious cases where the sexes appear to have exchanged characters—where the females are stronger, more pugnacious, and more ornamented than the males;—and where this is the case, the males assume the usually female duty of incubation.[1] Among fishes, when incubation is practised at all, it is usually undertaken by the male; and among fishes, as among birds and other animals, when there is any difference of colour between the sexes, the male is generally the brightest. "In most of the Lophobranchii (pipe-fish, Hippocampi, &c.) the males have either marsupial sacs or hemispherical depressions on the abdomen, in which the ova laid by the female are hatched. The males also show great attachment to their young. The sexes do not commonly differ much in colour, but Dr. Günther believes that the male Hippocampi are rather brighter than the females. The genus *Solenostoma*, however, offers a very curious exceptional case, for the female is much more vividly coloured and spotted than the male, and she alone has a marsupial sac, and hatches the eggs; so that the female of *Solenostoma* differs from all the other Lophobranchii in this respect, and from almost all other fishes, in being more brightly coloured than the male."[2] There are some cases of the same kind among insects. Among many genera in almost all orders the possession of wings is a sexual character, distinguishing the males alone; but in a few cases this is reversed, and the female alone has wings. Among insects and birds, and probably among all animals, where the sexual characters are thus reversed, the females seek the males, instead of the contrary.

Reversal in Man of another and a profounder kind.—There is, however, another and a far more profound reversal of the

[1] Darwin's *Descent of Man*, p. 201 *et seq.* [2] *Ibid*, p. 20.

usual character of the sexes which occurs in Man, and, so far as yet known, in no other species whatever. In all other species, beauty is developed in the sex where the passions are strongest, and, consequently, generally in the male; but in the human race, beauty is developed chiefly in the sex where the passions are the weakest, namely in the female. Also, though the love of ornament, especially during youth, is naturally strong in both sexes, it is much stronger among women than among men; and this is recognised as legitimate by the customs of all the most highly-cultured races, which permit and encourage this propensity among women with scarcely any limit, but narrowly restrict it among men. There is no doubt of the wisdom of this, but such usages are based, not on calculation, but on instinct. Thus, throughout the entire animal creation, wherever a mental nature is developed, there is a general tendency to a connection between beauty and love; but the nature of the connection is opposite in our race to what it is in any of the lower animals. I have no suggestion to offer on the reason and the significance of this, and of the other exceptions to the usual relations between the sexes which we have seen to exist. A satisfactory treatment of the subject is impossible so long as the very existence of such an agency as sexual selection remains a disputed question.

Beauty in Shells.—I will conclude this chapter with the remark, that there is at least one class of cases where beauty certainly does not in any way depend on the relation between the sexes. I mean the beauty of sea-shells. Nothing of the nature of sexual selection can act here, because the animals that form and inhabit the most beautiful sea-shells are of the same class with the snail, and certainly have not a mental nature sufficiently developed to appreciate beauty;—moreover, if any further proof is needed, the shells of the *Cypreæ*, or cowries, which in colouring are among the most beautiful of all shells, are during life concealed under the edges of the animal's mantle. The beauty of shells, however, does not depend on

colour or on general form alone. In some genera, especially in *Murex*, there is a fringe-like cornice of ornamental sculpture round the lip, which appears to be as purely ornamental as anything in human art.

Nature is not exclusively utilitarian.—Such facts as these, to my mind, go far to prove Mr. Wallace to be right in his conclusion that the phenomena of the organic world cannot be accounted for on utilitarian principles alone.[1]

[1] *Macmillan's Magazine*, October, 1877.

CHAPTER XVII.

METAMORPHOSIS AND METAGENESIS.

Development is Differentiation.—Organic development essentially consists in differentiation; that is to say, the process of development consists in the increasing unlikeness of tissues from each other, and the increasing separation of organs. When development is watched under the microscope (which can be done with many of those comparatively low animals that have bodies composed of transparent tissues, and with the eggs of fishes and frogs), the original structureless and homogeneous germ is seen to transform itself into different organs and tissues, each occupying its own part of the body of the developing organism.

Embryos of Higher forms resemble Lower forms.—From the truth that development consists in differentiation, it follows that the greatest differentiation is the highest development. Those organic species are the most highly developed in which differentiation, that is to say, the distinctness of the different organs and tissues, has been carried furthest; and those species are the lowest, or least developed, in which the original homogeneous germ has undergone the least differentiation, and remains most nearly in the original state. Consequently the undeveloped embryos of the higher forms bear some degree of resemblance to the mature states of the lower ones;—that is to say, an organism which has just begun a course of what is destined to be very high development, has some

resemblance to one which has completed a much lower course of development.

Metamorphoses explain and are explained by Evolution.—If then it is true that all organisms which are not perfectly simple are descended from simpler forms, we may accept it as a generally true conclusion, though subject to modifications and exceptions for reasons to be stated further on, that the embryonic and larval forms of any species resemble the mature forms of its ancestors; and that the development of the individual presents a short summary and recapitulation of the history of the evolution of the species.

Metamorphosis may be defined as development with change of plan; and we may expect to find that the facts of metamorphosis illustrate the theory of evolution, and are made intelligible by it. This is so on the whole, but there are many metamorphoses which in our present state of knowledge are most perplexing, and appear quite anomalous. Those of the winged Insects are the most familiarly known of all metamorphoses, and yet they are among the most difficult to understand and account for.

Metamorphoses of the Batrachia.—No metamorphoses appear to throw so much light on the process, whereby one class of organisms has been derived from another, as the transformations of the Batrachia (frogs, newts, &c.) from aquatic and water-breathing into terrestrial and air-breathing animals. In the transformation of a tadpole into a newt, a frog, or a toad, the respiratory and the motor systems are altogether changed; the branchiæ, or gills, wither and disappear; lungs are developed; legs bud forth; and in the frog and the toad, though not in the newt, the tail is absorbed and disappears. Some light is thrown on these transformations by the facts that among the water-breathing classes of animals generally the respiratory organs are remarkably variable in form and position —that in many cases they do not appear till a late stage of the

animal's development—and that in all the lowest organisms, and in many which are not among the lowest, there are no distinct respiratory organs, and the entire surface is a respiratory surface.

Loss of Metamorphosis: Land-newt.—The Batrachian class also contains good instances of the loss of metamorphoses through suppression of stages of development. Thus the land-newt (*Salamandra atra*), which lives in dry mountainous regions where there are no pools of fresh water, is an exception to the general law that Batrachians leave the egg in a tadpole form. It passes through the tadpole state before leaving the egg; and it is said that fully developed tadpole structure may be seen in the egg. The land-newt, unlike other newts, hatches its eggs within the body of the mother, and brings forth its young alive. This is easily explained as to its purpose;—the land-newt inhabits dry places where there are no pools of water, like those in which the eggs of other newts are laid and hatched. With this may be compared the case of the common ringed snake, which usually lays its eggs among sand, but, if kept where it has no access to sand, retains its eggs, and brings forth its young alive. This appears to suggest that the change from the habit of depositing the eggs to that of hatching them within the body, which thus occurs occasionally in the ringed snake, and has become a specific character in the land-newt, may be a result of the will of the animal. It must be remembered that this is a mere functional change; such viviparous birth as this is very far removed from the gestation of the Mammalia; though we can scarcely doubt that the ordinary or placental Mammalia are descended from implacental mammals, which probably resembled the *Ornithorhyncus* and *Echidna* more than any other known form.

Hylodes Martinicensis.—In another Batrachian, namely *Hylodes Martinicensis*, the metamorphosis appears to be lost altogether, and the mature frog structure is directly developed from the

germ, almost in the same way as in Lizards and other true Reptiles, and without passing through any tadpole state. It is interesting to observe that this frog leaves the egg with a tail, which, however, is absorbed and disappears on the first day of its independent life.[1] This is no doubt inherited from its tadpole-like ancestors, and is the equivalent of the tail that remains during the life of the newt, though it is absorbed and disappears in the frog and toad. This instance, and other instances of the same kind which we shall have to mention among the Crustacea, show that, although similarity of development and of larval form is a proof of true genetic affinity, yet dissimilarity in these is no proof of the absence of affinity. Had the entire Batrachian class lost their metamorphoses, so as to acquire their mature form by direct development from the germ, instead of passing through the tadpole state, the nearness of their affinity to Fishes would probably have never been suspected. There may not improbably be many true genetic affinities in the organic world, which for this reason will never be discovered.

Metamorphosis: how originated.—If the theory of Evolution is true, the larval forms in such cases as that of the Batrachians represent ancestral forms;—frogs and all other Batrachians are descended from tadpole-like fishes. What makes possible such a transition, is that variations sometimes occur at a not very early age; and when this occurs, the variations, according to Darwin, are generally inherited by the offspring at the same age. In the case now under consideration, the tadpole-like ancestors of the Batrachian class began to assume the Batrachian characters after they were fully developed as tadpoles, though perhaps before they had attained to full maturity.

Loss of Metamorphosis: how originated.—What makes possible the loss of metamorphoses, as in the case of the land-newt

[1] These facts are stated in *Nature*, 5th April, 1877, on the authority of Dr. Grundlach.

and the *Hylodes Martinicensis*, is the fact that variations are sometimes inherited at an earlier age than that at which they occurred in the parent: thus, if, as every believer in evolution will admit, the species now mentioned are descended from species which went through the usual Batrachian metamorphoses, the metamorphoses have in these cases disappeared by first occurring at an earlier period—namely, in embryonic life—as in the land-newt, and afterwards disappearing altogether, as in *Hylodes Martinicensis*. In other words, metamorphoses are lost by occurring at an earlier and earlier period of life, until they are simultaneous with the first development; and this last is equivalent to their disappearance.

It appears probable that the process of change which ends in the loss of metamorphoses has begun in the entire Batrachian class;—that is to say, the beginning of the metamorphosis occurs at an earlier age, and an earlier period of the development of the tadpole, than did the variation which gave to the ancestral fish a tendency towards the Batrachian form. If this is so, the tadpole resembles, not the mature form, but a young and immature form of the ancestral fish.

Natural Selection will favour the loss of Metamorphosis: Probable general tendency to direct development.—It is obvious that the loss of metamorphosis may in some cases be extremely advantageous to a species, by diminishing the chances of destruction during early life; and when this is the case, natural selection will tend to preserve those varieties and species which have shortened or altogether lost their metamorphoses. But selection can originate nothing; and Herbert Spencer's suggestion appears highly probable, that there is a general primary tendency in living beings to substitute direct for indirect development, by assuming the likeness of the parent from the first, and thus ceasing to pass through metamorphoses. Perfectly direct development, however, does not exist among any of the highest organisms.

The Metamorphoses of the Batrachia are adaptive: Their probable origin.—The metamorphoses of the Batrachia are adaptive metamorphoses: that is to say, their purpose is to adapt the animal to a new kind of life—to raise it from an aquatic to a terrestrial existence. It seems probable that the first impulse to the transformation of a tadpole-like fish into an air-breathing animal was given by the drying up of the pools of water in which it lived. This conjecture is supported by experiments on the Axolotl, a member of this class, which does not always undergo metamorphosis, but frequently remains all its life a water-breather, though with the feet of a perfect newt, and propagates in that state. As in all members of the class, its metamorphosis, when this occurs, partly consists in the withering of the branchiæ or gills; and it has been found that the change of the animal's colour, which normally accompanies the withering of the branchiæ, is promoted by their removal: an operation which does not appear to be injurious.

Metamorphoses which are not adaptive: The higher Crustacea.—There are metamorphoses which, unlike those of the Batrachia, do not appear to be adaptive. When the animal, at its various stages of transformation, lives in the same locality and leads the same kind of life, its metamorphoses cannot be regarded as adaptive; and, so far as I see, can be ascribed only to an innate impulse to development. This applies to the metamorphoses of the higher Crustacea (crabs, lobsters, &c.). The earlier transformations here are from one free-swimming form to another.

Progressive and retrogressive Metamorphoses.—The metamorphoses of the higher Crustacea resemble those of the Batrachia in being progressive;—that is to say, they are changes from a lower to a higher existence;—and so are those of the true or hexapod Insects. This is the general law of metamorphosis, but it is subject to some remarkable exceptions. One of the most important discoveries in zoology since Cuvier's time is that of the development of the Cirrhipedes or Barnacles from

crustacean larvæ. Cuvier, and Linnæus before him, knowing this remarkable class only in the mature state, regarded them as Mollusca; but no naturalist has hesitated to place them among or near the Crustacea, since it has become known that their larvæ are scarcely to be distinguished from other crustacean larvæ. The same is true of the *Lerneæ* and other Ichthyophthira, which in the mature state are parasitic on fishes, and were formerly supposed to be worms. These are adaptive metamorphoses, being accompanied by a total change in the mode of the animal's life: the larva is free, but the mature animal is absolutely or at least comparatively fixed. They are also retrograde metamorphoses, being changes from a higher to a lower existence. All retrograde metamorphoses are probably adaptive, but the converse is not true; the adaptive metamorphoses of the frog and other Batrachians are, as we have seen, not retrograde but progressive.

Characters of the Arthropod Classes.— The Crustacea are one of the four classes that constitute the Arthropoda, a great division of the animal kingdom, precisely coinciding with the Linnæan class of insects. The other three classes are the Arachnida, to which the spider and scorpion belong; the Myriopoda, or centipedes and millepedes; and the true or hexapod Insects, in which class alone wings are developed. Arthropods may be generally defined as segmented animals with jointed appendages. The segmentation is well seen in the Centipede; in the Spider it is almost obliterated through the coalescence of the segments. The jointed appendages are universal among the Arthropoda, except in a few degraded forms; they assume various modifications—antennæ, jaws, chelate or claw-bearing arms, legs, and swimming feet—all of which are homologous with each other, in the same sense that the arms and legs of man are homologous. It must be observed that, unlike the jaws of Vertebrates, those of Arthropods open horizontally. All the variously modified appendages now mentioned are found in the Lobster and Prawn. Segmentation is a character which Arthropods share with worms, but

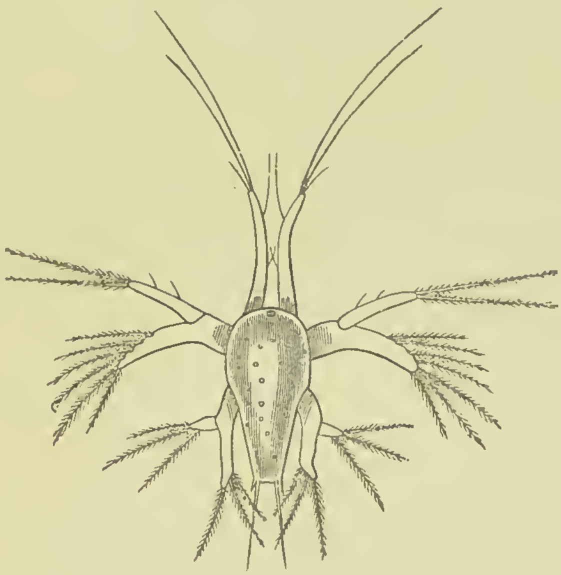
the jointed appendages or limbs, from which they derive their name, are altogether peculiar to this division. Both the body and the limbs are constructed on a plan opposite to that of Vertebrates, the hard parts being outside and the soft parts within.

Crustacean Metamorphoses: Nauplius larval form.—The larval form called a Nauplius stands in a relation to the Crustacea analogous with that of the tadpole to the Batrachia. So far as is yet known, all Nauplii are larvæ, and undergo transformations into some other form; no Nauplius is known to exist at present as a mature form, but it appears probable that the entire crustacean class is descended from an animal which must have once existed as a permanent Nauplius. A Nauplius is a minute animal of an oval form, with six swimming legs, but no antennæ or jaws, and with a single eye placed medially. It has the unusual character for an Arthropod, that its body has no trace of segmentation. The same, as we have mentioned, is true, or very nearly so, of the Spider; but it appears most probable that the two cases are really not similar, but opposite. In the Spider, which is one of the highest of all the Arthropods, the segments appear to have coalesced. The Nauplius, on the contrary, is one of the lowest Arthropod forms, and its entire body appears to be homologous with a single segment of one of the higher forms. This is supported by the fact, which we shall have to mention further on, that when a Nauplius develops into one of the higher Crustacea, a segmented body is formed, not by the body of the Nauplius becoming divided into segments, but by the intercalation of new segments between the body of the Nauplius and its tail.

The Legs of the Nauplius are not homologous with those of Insects.—The six legs of the Nauplius might suggest some affinity with the true or hexapod Insects. This, however, would be an altogether erroneous conjecture, for its legs are not

homologous with those of Insects. If their homologues in the Insects can be identified at all, they are not the legs, but the appendages of the head, the antennæ and jaws.

Unlike mature forms of similar Nauplii.—No other larval form is known—none, at least, of nearly so high an organization—which develops into such very different mature forms. Haeckel, in his *History of Creation*,[1] figures six Nauplii, of



Nauplius of a Prawn, magnified forty-five diameters. From Fritz Müller's *Facts for Darwin.*

which he remarks that if they "could be met with in this form in a sexually mature condition, no naturalist would hesitate to regard them as six different species of one genus." Yet their after history is as unlike as it is possible to imagine. Three undergo progressive metamorphoses, and rise in the scale of being; three undergo what must be regarded as retrogressive metamorphoses, and in their mature state have lost the power of locomotion.

[1] Vol. ii. p. 174, of the English translation.

Lepas.—One is transformed into a *Lepas*, or Barnacle. This belongs to the class of Cirrhipedes, which in the mature state retain no crustacean character except the jointed feet with which they send a current of water to the mouth in order to obtain food. Until their larval state was known they were generally classed as Mollusca.

Lernæocera.—Another is transformed into a *Lernæocera*, one of the order Ichthyophthira. These are external parasites on fishes, and have so completely lost the crustacean character that they were formerly supposed to be worms.

Sacculina.—Another becomes a *Sacculina*, belonging to the Rhizocephala,[1] and is still farther degenerated than the *Lernæocera*, being only a sausage-shaped sac, with roots extending into the flesh of the crustacean, on which it has become a parasite.

Cyclops.—Another becomes a *Cyclops*. This, as the name indicates, retains the single eye of the Nauplius, and appears to depart less than any other of the six from the Nauplius form. The Copepoda, to which the *Cyclops* belongs, have comparatively few feet, and their branchiæ or breathing-organs are in the immediate neighbourhood of the mouth.

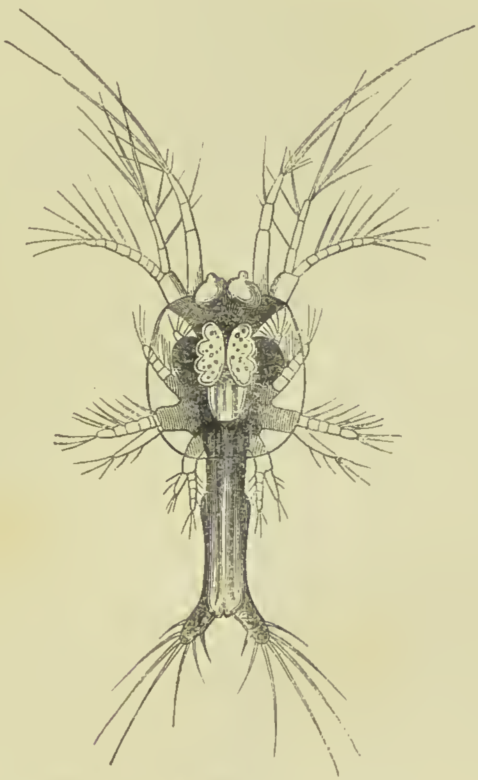
Limnetis.—Another is transformed into a *Limnetis*, having twelve pairs of leaf-shaped feet, which also serve as breathing organs. *Limnetis* belongs to the order Phyllopoda, which derives its name from the form of the feet.

Peneus.—Lastly, it has been ascertained by Fritz Müller that the Nauplius figured on p. 287 becomes a *Peneus*, or Prawn, a member of the Decapod order, which is the highest order of the Crustacean class, and contains the Lobster and the Crab.

[1] See p. 181.

This *Peneus* is the only Decapod which is known to begin its life as a Nauplius, though the Nauplius form of larva is very common among the lower Crustacea.

With the development of these similar Nauplii into such different mature forms, compare the fact that the embryos of a tortoise, a chicken, a dog, and a man—members of three



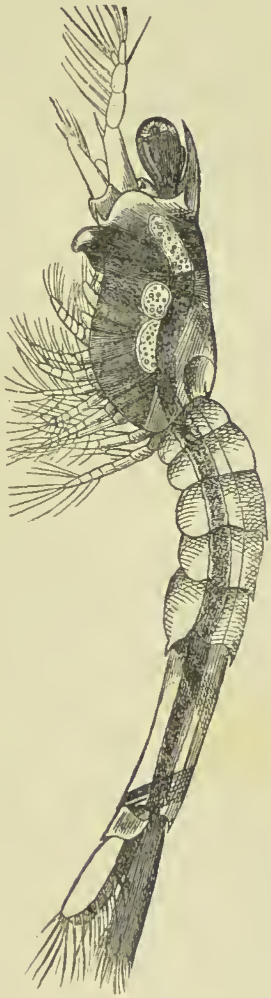
Young Zoea of the same Prawn, magnified forty-five diameters. From the same.

different classes of Vertebrata—are scarcely distinguishable.[1] A larva may be regarded as an embryo which has left the egg at an early period of development, and acquired the power of feeding itself.

[1] See the figures in Haeckel's *History of Creation* (English translation), vol. i. p. 306.

Older Zoea of the same Prawn, magnified forty-five diameters. From the same.

Metamorphoses of Müller's Peneus.—The metamorphoses of the *Peneus* here mentioned have been carefully traced by Fritz Müller, and form one of the most instructive chapters of zoology ever written.[1]



Mysis form of the same Prawn, magnified forty-five diameters. From the same.

The first two pairs of the legs of this Nauplius are transformed into antennæ, of which the Crustacea have two pairs; the third pair is transformed into the mandibles or anterior

[1] See Mr. Dallas's translation of Müller's *Facts for Darwin* (Murray, 1869).

pair of jaws. The part of the body of the Nauplius which bears these appendages becomes the head of the mature Prawn; the tail end continues to be the tail end, and development proceeds by the growth of segments between these, forming a long tail-like abdomen, which is the corresponding part to that usually, but inaccurately, called the tail of the Lobster. New limbs appear, a carapace or shell is developed from the head, and the two eyes of the mature form make their appearance. In this state the animal is called a Zoea. This form is very common among the higher Crustacea; most crabs appear to leave the egg as Zoeas.

The next stage is that called by Müller the Mysis or Schizopod stage. It differs from the Zoea chiefly in having acquired feet on the newly-formed segments. This changes into the mature form by some of the swimming feet acquiring chelæ or claws, while others posterior to these are changed into walking feet; and at the same time the respiratory function, which in the Nauplius took place probably through the entire surface, and in the Zoea through the lateral parts of the carapace, is assumed by branchiæ, which are developed on the thorax.

These changes are perfectly continuous. There is no abrupt change similar to the unfolding of the Insect's wings, nor is there any stage like the pupa or chrysalis stage of many Insects.

The stages of development represent the successive ancestors of the Peneus.—If the theory of evolution is true, it can scarcely be doubted that as the tadpole represents the fish from which the frog is descended, so the developmental stages of Müller's Prawn represents the ancestry of the entire order of Macrurous Crustacea, to which the Prawn and the Lobster belong. A Nauplius, or some form nearly resembling it, was probably the ancestor of the entire Crustacean class: a Zoea was descended from this, and became the ancestor of all the higher or Malacostracan Crustacea; a Mysis form was descended from the Zoea, and gave origin to the macrurous or long-tailed order,

though not to the crabs, which do not pass through the Mysis stage. The Nauplius stage, it is true, appears to be exceptional among the higher Crustacea, which mostly leave the egg in the Zoea form; but the fact that the Nauplius form occurs among the higher Crustacea at all is sufficient to prove the affinity of the entire order; and its absence in most cases only shows that it has dropped out of the chain of successive developmental forms, just as the tadpole stage has been lost in the case of the *Hylodes Martinicensis.* In the case of the Lobster, the Zoea stage also has dropped out, and the animal leaves the egg in a form resembling the Mysis. Finally, the fresh-water Crayfish undergoes no metamorphosis at all.[1]

Probable reason of loss of metamorphosis in the fresh-water Crayfish.—The fact of the development of the fresh-water species being direct, is very significant. The fresh waters have, it is tolerably certain, been colonized from the sea, and not the reverse. The change from salt to fresh water, like any other change, acts as a stimulus to variation; and variation in this case has taken the form of making development more direct. This is also a change which natural selection will have tended to assist; for on coming into a new habitat, the chances must be greatly against any species finding food and surroundings suited to both the larval and the mature forms; and the process of adaptation must be much facilitated by dropping out the larval stage of development altogether.

These facts give no support to Darwinism.—The facts of Crustacean metamorphosis, which I have now described in extreme outline, appear to tell very strongly in favour of the general theory of evolution. But I cannot agree with Müller that they at all favour the specially Darwinian form of that theory. Natural selection among spontaneous accidental variations may, at least, help to account for very great changes in the organism to correspond with changed conditions of life. It may,

[1] Stated by Müller (p. 47) on the authority of Rathke.

no doubt, account in part for the change in the respiratory and motor systems of the first race of tadpoles that were transformed into air-breathing animals, when the waters in which they lived began to dry up. But it does not follow that the same process is likely to be sufficient while the conditions of life remain unchanged; and this appears to have been the case throughout the greater part of the evolution of the higher Crustacea, because the Nauplius, the Zoea, and the Mysis forms are all freely swimming animals, living under conditions which do not sensibly differ. The minute and random variations which alone Darwin's theory recognises are unlikely to work great changes under unchanging conditions of life; and this for two reasons. In the first place, such spontaneous variations are then less likely to occur, because permanence of circumstances promotes constancy of form, while on the other hand changes of circumstances promote variation; and in the second place, if under such conditions they do occur, they will be less likely to give any sensible advantage to the individuals possessing them than changes of similar magnitude occurring along with changing conditions. I cannot think that the evolution and the metamorphoses now described can be referred to any other cause than a formative impulse impressed on living matter at the beginning.

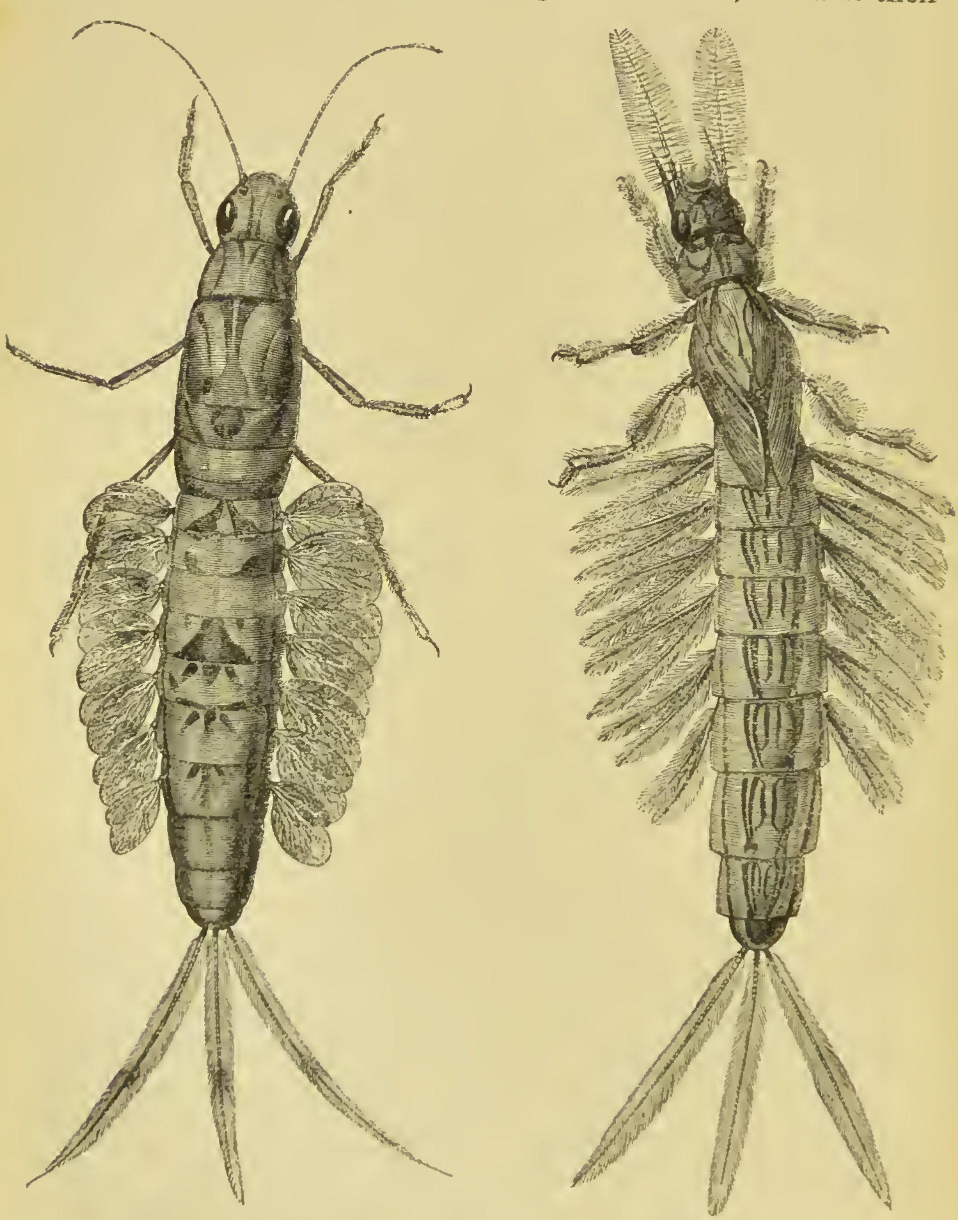
Besides this general argument, a remarkable special argument on the subject is yielded by Müller's very interesting researches on the development of his prawn. He says of its Mysis that "the long abdomen, which just before was laboriously dragged along as a useless burden, now, with its powerful muscles, jerks the animal through the water in a series of lively jumps."[1] The Nauplius has no abdomen; this part is acquired when the Nauplius develops into a Zoea, and consists of segments which appear in front of the tail of the Nauplius. Darwin's theory will account only for changes which are immediately beneficial; and Müller's account appears to show that its abdomen is not immediately useful to this Zoea, but is developed for the purpose

[1] *Facts for Darwin*, p. 61.

of subsequently becoming useful as a swimming organ and developing feet upon its surface. It may be suggested that the abdomen has some physiological function which makes it useful to the Zoea, but this seems utterly improbable. I do not wish to overstate this argument. There are abundant instances of structures which were probably developed at first under the influence of use, coming to be developed before they can be of use. This is true of every character which first appeared after birth, and was strengthened by use and habit, and preserved by natural selection, until it became embryonic. Still, on Darwin's principles, the abdomen of this Zoea must have been originally developed because it was useful, and it seems impossible to give any reason why it has come to be developed before it is useful.

Metamorphoses of the true Insects, and development of their Wings.—The metamorphoses of the true Insects present much greater difficulties than those of the Crustacea. Among the Crustacea we have seen that each temporary form worn by the animal during its development probably represents the mature form of one of its remote ancestors. But this does not appear to be true of the Insects, as will appear from a study of their metamorphoses. Insects are the only invertebrate animals that have wings, and their wings resemble nothing else in the animal kingdom. But, though characteristic of the insect class, wings are not universal in it. Some insect orders are wingless, and there are wingless genera in most of the orders. In many cases the wings are a sexual character, being possessed by the males alone; and in all cases they are acquired by metamorphosis: no insect leaves the egg with wings. These three facts are all mutually connected; characters which are late in development tend to be variable as between species of the same order, and the same is true of secondary sexual characters—that is to say, characters which belong to one sex only without appertaining to the reproductive system. It is obvious that any account of the origin of the class of Insects must be unsatisfactory, unless it can explain the origin of the wings; for it

would be contrary to all analogy to suppose that organs so very peculiar as these, or indeed any organs whatever, could at their



Larva of *Cloe bioculata*. Larva of *Ephemera vulgata*.
From Duncan's *Metamorphoses of Insects*.

first origin be suddenly produced; and the wings are developed in a comparatively short time during the last period of larva

life, and unfolded, not gradually, but all at once, at the final metamorphosis.

The Wings are developed as part of the Respiratory System.—All naturalists are now agreed that the wings are morphologically part of the respiratory system. Insects breathe by means of tracheæ or air-tubes, which open on the animal's side and ramify through the body. The wings are formed on the outer termination of the tracheæ; and during the development of the wings, and before they come into activity, their veins appear to be tubes which are continuous with the tracheæ. Dr. Duncan says [1] of the final metamorphosis of the small tortoise-shell butterfly:—"The wings, then scarcely as large as hemp-seeds, are gradually distended at their base, and are perceptibly enlarged at each respiration." The wings appear to be homologous with the external branchiæ of some aquatic larvæ, as the *Cloe bioculata*, the *Ephemera vulgata*, and the *Phryganea clavicornis*. "The adult Insect," says Dr. Duncan, "becomes an air-breather, and spiracles (or mouths of the tracheæ) are developed in its sides exactly in the places where the gills were attached during its fish-like life. In the larvæ of the May-flies (*Ephemera*) the branchiæ are formed of expansions of the skin, which are very delicate, thin, and variously folded and fringed, and they are attached in pairs to the first seven segments of the abdomen. The tracheæ are included in the folds, and are continued into the body of the larvæ, and they transmit the purified air to it; but the gills disappear during metamorphosis." [2] In *Pteronarcys regalis*, an Insect inhabiting damp places, these branchiæ remain through life.[3] This is consequently a perennibranchiate Insect, and its case is analogous to the perennibranchiate Batrachians, which, while acquiring lungs, do not lose the branchiæ of their tadpole state. In the existing species, as we have seen, these branchiæ are developed on the abdomen, and

[1] Duncan's *Transformations of Insects*, p. 51.
[2] *Ibid.* p. 48.
[3] Rolleston's *Forms of Animal Life*, Introduction, p. cx.

such a position, for mechanical reasons, would be an impossible one for wings. But, considering the remarkable variability of the respiratory organs of aquatic invertebrates generally, there is nothing improbable in the supposition that such branchiæ in one species were developed on the thorax, and came into use as swimming organs, and ultimately as wings. It is mentioned by Sir John Lubbock that the muscles which are attached to the branchiæ of the larvæ of *Cloe* "in several remarkable points resemble those of the true wings."[1]

A Swimming Hymenopteron.—It has been mentioned, in support of this hypothesis, that an insect has been lately discovered by Sir John Lubbock, and named *Polynema Natans*, which uses its wings in swimming. But, interesting as is this fact, it is scarcely relevant to the present question; for the *Polynema* belongs to the order Hymenoptera, the same order that contains the Bee and the Ant, which is perhaps the highest of all the Insect orders, and does not appear in any way to point to the origin of the class.

The first Insects were probably Air-breathers.—If the conclusion is accepted which is here stated as to the probable origin of the Insect's wing, it may appear a necessary inference that the first Insects were water-breathing animals. This, however, does not appear to have been the case; it seems more probable that Insects were an air-breathing class from the first; that aquatic respiration was always as exceptional among the Insects as aërial respiration among the Crustacea, and that wings were first formed in one of those exceptional families which took to an aquatic life, and developed branchiæ upon their tracheæ. The reasons for this apparently strange conclusion are as follow:—

Reasons for this Conclusion.—As we have seen, the branchiæ, or water-breathing organs, of some larvæ, which appear to be

[1] Monograph of *Collembola and Thysanura*, published by the Ray Society, p. 53. *Cloe* is called *Chloeon* by Sir John Lubbock.

homologous with the wings of mature Insects, are developed on the external terminations of the tracheæ or breathing-tubes; and, though in the larvæ in question the tracheæ serve for aquatic respiration, yet tracheæ appear to be essentially and originally air-breathing organs; for air-breathing organs are in general internal, so as to bring the air into the body: while water-breathing organs are in general external, so as to bring the blood out into the water. Consequently, when a water-breathing Insect has its branchiæ formed in connexion with tracheæ, it appears most probable that the tracheæ are inherited from an air-breathing ancestry; for internal breathing organs like tracheæ could not be formed in a water-breathing race. It may be argued, in opposition to these views, that the tracheæ of the Insects and the Myriopoda (centipedes) are homologous with the "water-vascular system" of the lower worms, or the "segmental organs" of the higher worms or Annelids. But this appears improbable, because the Crustacea, which are the characteristically water-breathing class of Arthropods, have no water-vascular system, and nothing resembling either the tracheæ of Insects or the so-called lungs of Spiders.

Further, not only is aquatic respiration exceptional among Insects, but when it does occur, there is no uniformity in the respiratory organs. Sir John Lubbock remarks:—"From the various modes by which respiration is effected among different groups of aquatic Insects, we are justified in concluding that the original Insect stock was a land animal."[1] Were the water-breathing Insects representatives in that respect of the original stock of the class, then their respiratory organs would resemble their origin and resemble each other; but when we find them unlike in the different water-breathing groups, we conclude them to have been separately developed. In the same way aërial respiration is exceptional among the Crustacea, and the respiratory organs of the various air-breathing groups are quite unlike each other, showing that they also have been developed separately.[2]

[1] *Collembola and Thysanura*, already quoted, p. 53.
[2] See Müller's *Facts for Darwin*, already quoted.

The hypothesis that the branchiæ which have been developed into wings were of later origin than the tracheæ, and of later origin than any other important organ, agrees also with the facts that the presence of wings, though general in most orders, is inconstant, and that when they exist they are never developed until the final metamorphosis.

The first Insects probably resembled Campodea.—Finally, Sir John Lubbock has given what appears to be strong reasons for thinking that the first Insects resembled the Thysanura, an order which are all air-breathers and all wingless, and undergo no metamorphosis. He has gone so far as to indicate the genus *Campodea* as that which has probably remained nearest the original form. *Campodea staphylinus*, as figured by him,[1] is an Insect about a quarter of an inch in length, with strongly-marked segmentation of the body, no wings, six legs, a pair of jointed antennæ about one-fourth of the length of the body, and a pair of jointed tail-bristles a little longer than the antennæ. (In some Thysanura these tail-bristles are used for leaping, whence the name of spring-tails.) *Campodea* has a strong resemblance to what the larva of *Cloe*, figured on p. 296, would be without its leaf-like branchiæ; and Sir John Lubbock, in another memoir, states that the metamorphosis of the latter is remarkably continuous and free from abrupt changes, from which he draws what appears to be the reasonable conclusion, that it comes tolerably near to representing the original type of Insect metamorphosis.

Difficulty about the Transformation of the Mouth in some Metamorphoses.—Difficult as is the question of the origin of the Insect's wings, the metamorphoses of the parts of the mouth present greater difficulties still. Among some Insect orders the organs of the mouth are re-developed during the final metamorphosis, at the same time with the development of the wings. While this process is going on the Insect remains in the pupa or

[1] See plate 50 of his work above referred to.

chrysalis state, during which it is quite inactive and does not feed. The necessity for the Insect to enter into this state, which may almost be called re-entering into the egg, does not depend on the development of the wings, but on the transformation of the mouth. Many Insects, as, for instance, the Orthoptera (grasshoppers, &c.), acquire wings without the mouth being re-developed, and they do not enter into the chrysalis state, but develop their wings without any cessation of activity; and others, among which are the wingless working ants, pass through the chrysalis state without ever acquiring wings. It is obvious that such a state is necessary, because a mouth in the act of undergoing transformation would be incapable of work, like a machine while under repair. It is remarkable that those Insects which pass through this state have the widest distribution, in consequence probably of its being, like the egg state, favourable to dispersion by driftwood and similar means.[1]

Chrysalis state.—These remarks, however, do not in any way explain how the chrysalis state can possibly have originated. The total change from the Tadpole to the Frog, or from the Nauplius to the Prawn, is almost, if not quite, as great as the total change from the worm-like larvæ of Hymenoptera or Diptera to the mature winged forms; but the metamorphoses of the Batrachia and the Crustacea are gradual and continuous; they present nothing comparable to the almost sudden development of the Insect's wings, and nothing resembling the chrysalis state. Indeed, there is nothing in the entire animal kingdom at all like the latter, except the "encysted" state of many Protozoa and parasitic worms. Sir John Lubbock suggests that the chrysalis state has been produced by the crowding together into a short time of a series of changes, which at first were gradual; and this is probably true, because gradual change is the rule in the organic world, and rapid, almost sudden, change, like that of the chrysalis into the winged Insect, is the exception. But

[1] Rolleston's *Forms of Animal Life*, Introduction, p. cxiii.

this does not account for the re-development of the organs of the mouth. On this subject the following suggestion has been made by Sir John Lubbock :—

Re-development of the Organs of the Mouth.—In some orders, as for instance the Lepidoptera (moths and butterflies), the mouth of the larva is mandibulate and adapted for biting, while that of the mature form is suctorial. Sir John Lubbock states that the mouth in the Thysanura is intermediate in structure between the mandibulate and the suctorial types; and he thinks it probable that the first Insects had such a mouth, from which the various and more specialised forms of mouth now found in both the larval and the mature forms have descended. He endeavours to account for the very surprising fact of the larva and the mature Insect in many cases having different types of mouth structure, by the suggestion that the larva and the mature Insect were placed in circumstances where different forms of mouth were needed by different kinds of food, and that natural selection produced in both cases the forms of mouth that were needed. This, however, seems to be putting on the theory of natural selection a strain that it will not bear; but I have not any better theory to propose. The transformation of a mandibulate and biting mouth into a suctorial one, in the metamorphosis of the caterpillar into the butterfly, is one of the most wonderful of all facts in zoology, and appears to be an unsolved difficulty of the theory of evolution.

Peculiar Metamorphosis of some Diptera.—Some of the Diptera (two-winged flies), while in the chrysalis state, undergo a very remarkable process of almost total re-development. Instead of the tissues of the larva being transformed into those of the perfect Insect, they are as it were melted down, except at certain spots, into an almost liquid substance, out of which the tissues of the winged Insect are developed. Mr. Mivart[1] has based on

[1] *Genesis of Species*, p. 51.

this fact an argument against Darwin's theory; and it certainly appears to point to some law of life and development quite distinct from natural selection.

Larval forms of Insects do not represent Ancestral forms, as do those of Batrachia and Crustacea.—We have seen that among Batrachia and among Crustacea the larval forms probably represent ancestral forms. But this cannot be true in the same sense among Insects. We have seen that the Frog is probably descended from a tadpole-like fish, and the Prawn from a Nauplius; but the Butterfly is not descended from a caterpillar, nor the fly from a maggot. In the case of Müller's Prawn, the perfect form is descended from a Mysis-like animal, the Mysis form from a Zoea, and the Zoea from a Nauplius. But the winged Insect cannot be descended from a chrysalis, because the motionless chrysalis can never have been the mature reproductive state of any species whatever; and it appears equally impossible that the suctorial Butterfly can be descended from the mandibulate caterpillar, because the intermediate stages of mouth structure would be inefficient. It thus appears certain that the "complete metamorphosis" of those Insects which pass through the chrysalis state and undergo re-development of the organs of the mouth, unlike the metamorphoses of the Crustacea and the Batrachia, is not original or primitive, but has been acquired;—and the ancestry of the class is most truly represented by the so-called "incomplete metamorphoses," in which there is no re-development of the mouth, and no inactive chrysalis state. To this class of metamorphoses belongs that of *Cloe* or *Chloeon*, which, as we have seen, Sir John Lubbock indicates as probably most nearly resembling the original Insect metamorphosis.

Possible Origin of the Maggot form of Larva.—The resemblance of a caterpillar to a Centipede, though obvious enough, is no proof of kindred. The nature of the connection between Insects and Myriopods is a debatable question; but, whatever

it may be, Insects are certainly not descended from Myriopods; and it appears most probable that the resemblance of the caterpillar to the Centipede is merely one of external form and appearance, like that of a Whale to a Fish, or of a Barnacle to a Molluscan. But the resemblance of the grubs which are the larval forms of Hymenoptera and Diptera to worms, is perhaps of a different nature, and may be due to reversion to a worm-like ancestor, from which not Insects only, but all the Arthropod classes, are descended. This reversion appears to be due to abundance of food and inactivity of life. Sir John Lubbock says[1]:—"The larvæ of Lepidoptera live on plants; activity to them would be useless, and they do not possess it. The larvæ of most Hymenoptera (for instance, of the Bee, Wasp, Cynips, &c.), of Diptera, and of some Coleoptera (Beetles), live in circumstances which call for even less locomotion, and have relapsed almost into the condition of their far-distant vermiform ancestor."

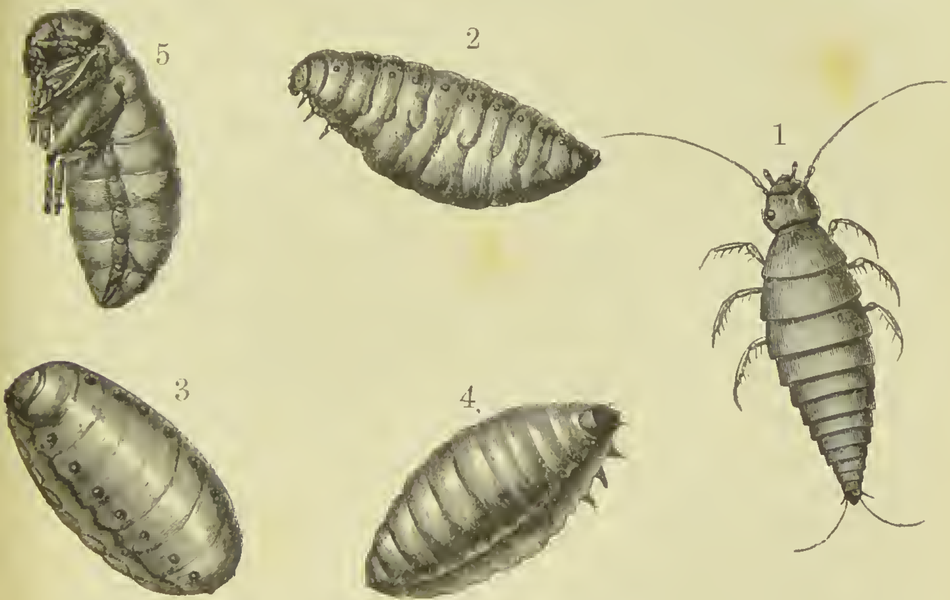
Metamorphosis of Sitaris.—By the light of these observations, the metamorphoses of *Sitaris*, which are the most exceptional in the whole of the wonderful class of Insects, seem no longer unintelligible. "The first larval form of a certain beetle, the *Sitaris*, as described by M. Fabre, is a minute, active Insect, furnished with six legs, two long antennæ, and four eyes. These larvæ are hatched in the nest of a bee; and when the male bees emerge in the spring from the burrows, which they do before the females, the larvæ spring on them, and afterwards take an early opportunity of crawling on to the female bees. When the latter lay their eggs, one in each cell, on the surface of the contained honey,[2] the larva leaps on the egg and devours it. It then undergoes a complete change; its eyes disappear, its legs and antennæ become rudimentary, and it feeds on honey; so that it now more closely resembles the ordinary larvæ of Insects.

[1] *Collembola and Thysanura*, p. 53.

[2] It will be perceived that this is a different species from the hive-bee.

Ultimately it undergoes further transformations, and finally emerges as a perfect beetle."[1]

Similar facts in the Metamorphosis of Flies.—It will be seen from the figures that the earliest form of the larva is much more like a mature insect than are any of its subsequent stages. There is some evidence that this is only the extreme of what is normal in insects which pass through a maggot or vermiform



Metamorphoses of *Sitaris humeralis*. From Duncan's *Metamorphoses of Insects*.
1. Larva in its earliest form. 2. Larva in its second form. 3. False pupa or quiet larva.
4. Larva in its fourth stage. 5. Nymph.

larva state. "Professor Owen believed that the larvæ of such insects as the Orthoptera, Neuroptera, &c. (which pass through neither a maggot nor a chrysalis stage), exist in the maggot form in the egg; but the observations of Mr. Newport on *Meloe*, and of Fritz Müller, of Weissmann, and many others, go far to prove that this is not so;—that the maggot form is intermediate, the half-developed embryo, and the pupa (?) or perfect insect, being most alike."[2] It is also asserted by Mr. Lowne,

[1] Darwin's *Origin of Species*, fourth edition, p. 394.
[2] B. T. Lowne in *Nature*, 4th January, 1872, p. 181.

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that "mandibles and maxillæ (similar to those of the perfect insect) exist in the egg (of the fly) twelve hours before the young maggot emerges, together with the fore and hind head segments; and that these have all disappeared when the egg hatches."[1] "The mouth organs of the imago (or perfect insect) are not the mouth organs of the larva, nor are they formed by their modification, but they are foreshadowed in the egg before the mouth organs of the larva are formed. It is the mouth organs of the larva which are new formations, not those of the imago."[2]

Summary. Probable interpretation of these facts.—The most probable interpretation of these facts appears to be, that the first insect that acquired wings left the egg with the legs, antennæ, and mouth developed, and passed through a gradual and continuous metamorphosis, consisting in little more than the transformation of branchiæ into wings;—and that the maggot and chrysalis stages have been subsequently intercalated between the earliest and the final or perfect stages.

Relation of Insects to the rest of the Arthropoda.—Before leaving this subject, we have a few remarks to make on the relation of the Insects to the other Arthropod classes.

There is much reason for believing that the origin of the entire Arthropod division is to be sought among the lower Crustacea, in some form resembling the Nauplius. But beyond this there appears to be no agreement. The best suggestion yet made is, perhaps, that at the conclusion of Müller's *Facts for Darwin*. "For the Insecta alone, the development of the Malacostraca (or higher Crustacea) may, perhaps, present a point of union. Like many Zoeas, the Insecta possess three pairs of limbs serving for the reception of nourishment,[3] and three pairs serving for locomotion. Like the

[1] B. T. Lowne in *Nature*, 4th January, 1872, p. 183.

[2] *Ibid.* 7th December, 1871, p. 101.

[3] These three pairs of modified limbs are "a pair of mandibles and two pairs of maxillæ, the hinder pair of which are coalescent, and form the labium."—*Huxley.*

Zoeas, they have an abdomen without appendages: as in all Zoeas, the mandibles are destitute of palpi. Certainly but little in common, compared with the much which separates these two animal forms. Nevertheless, the supposition that the Insecta had for their common ancestor a Zoea which raised itself to a life on land, may be recommended for further examination." To this I would add that a connexion is shown to exist between the Malacostraca and the Insects, and also between these two and the Scorpions (which belong to the Arachnida), by the remarkable fact that in these three groups, when the segmentation can be made out, the segments of which the animal is composed generally number twenty-one, counting the tail end as a segment. The only assignable reason for this is a common ancestry.

But what is the relation of the Myriopoda (centipedes and millepedes) to the other Arthropod classes? Among the Myriopoda, as among the lower Crustacea or Entomostraca, the number of segments varies greatly. Does not this separate them from those groups in which the number of segments is uniform? We must not answer this question too hastily. The presence of such a common character proves true affinity between groups; but its absence does not necessarily prove the absence of affinity, for it may have been lost by reversion. Nevertheless, when we see such a character as the number of segments—being generally neither more nor less than twenty-one—tolerably constant throughout the three vast groups of the Malacostraca, the Arachnida, and the Insects, and totally absent in the Myriopoda, it seems difficult to doubt that it points to a true affinity between those groups possessing it, which they do not share with the group that does not possess it. On the other hand, the Myriopoda resemble the Insects in the absence of palpi on the mandibles, which the Crustacea and the Arachnida possess; in the respiration, which is tracheal; and in having one pair of antennæ, which appear to be organs of sense (the Malacostraca having two pairs like those of Insects, and the Arachnida one pair, which are modified to serve as

organs of prehension). Huxley,[1] than whom there are few, if any, higher authorities, thinks there is a specially near kindred between the Myriopoda and the Insects. But against this, besides the argument from the number of the segments, it is to be mentioned that the Myriopoda resemble the Crustacea, and differ from Insects and Arachnids, in growing by the intercalation of new segments between those first formed, while Insects and Arachnids do not increase the number of their segments during growth. The resemblance between the tracheal systems of the Myriopoda and the Insects is no doubt very remarkable; but many Arachnids have similar tracheæ; and when we consider the variability of respiratory organs generally, it is perhaps not impossible that these systems may have been separately evolved in these three classes.

Suggestion of a possible separate descent of Myriopods from Worms through Peripatus.—At the point to which our knowledge of the affinities of the various Arthropod classes was brought by the publication of Müller's *Facts for Darwin*, it appeared almost certain that all those classes must be descended from a Nauplius form. But an unexpected light is thrown on the subject by Mr. Moseley's researches on *Peripatus capensis.*[2] Peripatus is a true Arthropod, having jointed feet; in appearance and habits it is like a Myriopod, and like them it is a land animal breathing by tracheæ; in its movement it is described as resembling a caterpillar. But in two very important characters it differs from Myriopods and all other Arthropods, and resembles Worms. The body is capable of being lengthened and shortened, and the two ventral nervous cords (which in Worms and Arthropods correspond in importance to the spinal cord of Vertebrates) are quite separate as in Worms, instead of being closely united as in Arthropods. These

[1] See the review of Haeckel's work in Huxley's *Essays and Critiques.*

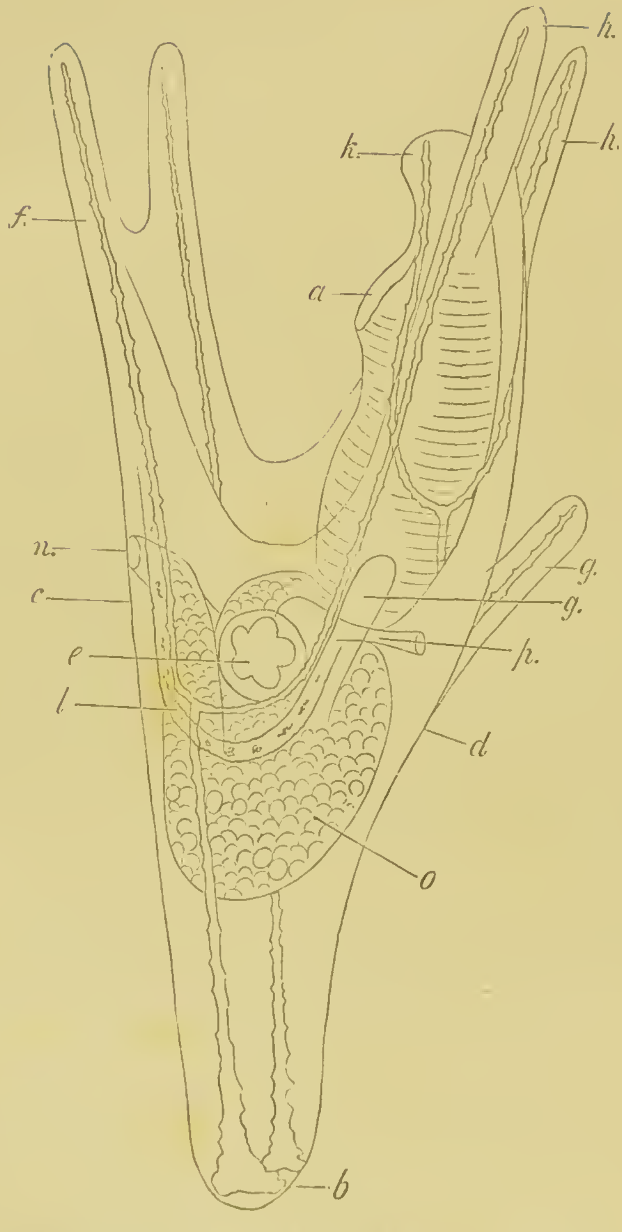
[2] Communicated to the Royal Society on the 21st of May, 1874, and printed in their *Philosophical Transactions.* An abstract is also printed in the *Annals of Natural History* for September, 1874.

characters constitute true affinity with Worms, and affinity of a kind which apparently must be direct, and not due to reversion. *Peripatus* consequently appears to be a connecting link between Worms and Myriopods; and if the Myriopoda stood alone, we could scarcely doubt they were descended from the Annelids, or higher Worms, through some form resembling *Peripatus*.

But we have seen that there is strong reason for believing Crustacea, Insects, and Arachnids, to have a common origin, and to be descended from a Nauplius. Now the Nauplius is certainly not descended from *Peripatus* or any other air-breathing animal. If then the Myriopoda are descended from a form resembling *Peripatus*, and the other Arthropod classes from a Nauplius, this is probably the most remarkable instance in the whole of the organic kingdoms of independent similarity produced by parallel variation. There is, however, much difficulty in the way of accepting this conclusion; for if it were true, we might reasonably expect to find evidence of it in the facts of development; and there appears to be none such; on the contrary, Myriopods, at the beginning of their development, are like other Arthropods.[1] We must consequently wait for more light on this most difficult question.

Metamorphoses of the Echinodermata.—The transformations of some of the Echinodermata (*e.g.* Star-fish and Sea-urchin) are quite as wonderful as any which we have yet mentioned, and appear to effect even a more fundamental change. The Frog and the Tadpole are alike Vertebrates; the *Peneus* and its *Nauplius* larva are alike Arthropods; and though the maggot larvæ of many Insects are not Arthropods—that is to say, they are without jointed limbs—yet this is probably to be explained by reversion to the character of an ancestor among the lower orders of Worms. But the *Bipinnaria* larva of a Star-fish or the *Pluteus* larva of a Sea-urchin are not Echinoderms; the larva

[1] See Dr. Duncan's *Metamorphoses of Insects*.



Pseudembryo of *Echinus lividus*, nearly mature. After Müller. From Sir Wyville Thomson on the "Embryology of the Echinodermata," in the *Natural History Review*, Oct. 1864.

a, mouth; *b*, club-shaped dilatations of the body-styles or calcareous rods supporting the body; *c*, posterior surface; *d*, anterior surface; *e*, echinoderm disk: *f*, posterior body appendages; *g*, anterior body appendages; *h*, primary oral appendages; *k*, accessory oral appendages; *l*, ciliated fringe; *n*, anus; *o*, granular hood covering the stomach; *p*, vesicle and pore, the rudiment of the madreporic tubercle and sand canal of the embryo.

and the mature animal are totally unlike in anatomical structure, or at most do not resemble each other more nearly than do a winged Insect and a maggot larva.

The accompanying illustration shows a *Pluteus*, with the "echinoderm disk," or "true embryo" of the sea-urchin, visible in the middle of its body. Unlike the mature Echinoderms, the tissues of these larvæ are transparent; and the larvæ are bilaterally symmetrical, unlike the mature animals, most orders of which present an approximately perfect radial symmetry, consisting of five equal parts disposed round a centre, like a flower of five petals.

In these larvæ the sarcode, or transparent structureless substance of their bodies, becomes in parts slightly fibrillated, thus forming a kind of rudimentary muscular tissue; and in the *Pluteus*, though not in the *Bipinnaria*, a skeleton, consisting of a "somewhat complicated framework of delicate, hollow, calcareous rods,"[1] is formed in the sarcode. Both of these structures belong to the larva only; in the *Pluteus* they disappear by absorption, and are not transformed into any part of the structures of the mature Sea-urchin;—the external and muscular parts of the *Bipinnaria* are neither transformed nor absorbed, but when the Star-fish is matured it casts off the *Bipinnaria*, which continues to live for some days.

Usual development of Aquatic Invertebrates.—Sir Wyville Thomson is of opinion that this mode of development is only the extreme form of that which is usual among aquatic Invertebrates. They generally begin life in the form of a freely swimming ciliated germ, which "increases in size by absorption through the general surface. Very usually various lobes and fringes are produced, frequently richly ciliated, extensions of a transparent sarcode-investing layer, within which—

[1] Sir Wyville Thomson on the "Embryology of the Echinodermata," reprinted from the *Natural History Review*, for October, 1864, p. 1. See on this subject the entire article, and also a previous one, of which it is a continuation, in the same *Review* for July, 1863.

but bearing to it obscure relations in form—the nascent organs of the true embryo are slowly differentiated."[1] When the permanent organs, that is to say the organs of the perfect form, are sufficiently matured, the external layer of sarcode, with its "lobes and fringes," is absorbed and disappears.

Larval form of a Nemertean Worm.—Aquatic Worms and Mollusca are generally developed in this manner. The development of temporary organs out of the external sarcode layer is carried much further in some species than in others. Metschnikoff has traced the development of a Nemertean worm belonging to the genus *Lineus*, the larval form of which is called by him a *Pylidium*;[2]—its lobes and fringes, and its entire form, bear no assignable relation to the form of the worm into which it is ultimately transformed.

Re-development is probably never total.—It appears most probable that in no metamorphosis does total re-development occur; —that no metamorphosis is comparable to the dissolving of a dimorphic substance from the crystalline state and crystallizing it again in a totally different form. The metamorphoses which come nearest to this are that of the worm-like maggot into the winged Insect, and that of the Pluteus or Bipinnaria into the Echinoderm. Of all known metamorphoses, perhaps the discontinuity is most decided, and the identity between the larva and the mature form least maintained, in that of the Bipinnaria into the Star-fish; for, as we have seen, the Star-fish, when it is formed, does not absorb the Bipinnaria with its motor organs, but casts it off in mass. Even in this extreme case, however, the Star-fish appropriates part of the alimentary canal that has belonged to the Bipinnaria; and this appears to show, contrary to Sir Wyville Thomson's view, that the Echinoderm is really the same individual with its larva;—the cast-off body of the

[1] From Sir Wyville Thomson's article already quoted, p. 28.

[2] Figured in Dr. M'Intosh's monograph on the British Nemerteans, published by the Ray Society, pp. 120 and 121.

Bipinnaria not being regarded as an individual animal at all, but only as a disused part of the animal apparatus, which, like any cut-off part of one of the lower organisms, continues for some time to show signs of life.

Great variability of Echinoderm Metamorphoses.—One of the most remarkable facts connected with the metamorphoses of the Echinodermata is their extreme variability. "In each order (of Echinodermata) it appears to be exceptional, and in certain cases it is known to be carried to its most abnormal degree in one species, while in a closely allied species of the same genus the mode of reproduction differs but slightly from the ordinary Invertebrate type. It seems highly probable that even in the same species, the development and independence of the first zooid may be carried to a greater or to a less degree according to circumstances." [1] And Sir Wyville Thomson states that this mode of development seldom occurs in the Echinoderms of the Southern hemisphere;—a fact which deserves to be regarded as one of the most wonderful of all facts of geographical variation.[2]

Are these Metamorphoses primary or acquired?—The question arises, how these extraordinary metamorphoses of the Echinodermata can have arisen. Are they primary, like those of Frogs, Crustaceans, and such Insects as *Cloe* or *Ephemera?* [3]

[1] Sir Wyville Thomson's paper of July 1863, p. 1.

[2] Sir Wyville Thomson, writing in the Linnean Society's *Journal of Zoology*, vol. xiii. p. 56:—"I was greatly surprised to find that in the southern seas a large proportion of the Echinoderms of all orders (with the exception perhaps of the Crinoids, with regard to which we have no observations) develop their young after a fashion which precludes the possibility, while it nullifies the object, of a pseudembryonic perambulator; and that in these high southern latitudes the formation of such a locomotive zooid is apparently the exception. This modification of the reproductive process [common in the Echinoderms of the southern seas] consists in all cases, as it does likewise in those few instances in which direct development has already been described, of a device by which the young are reared within or upon the body of the parent, and are retained in a kind of commensal connexion with her until they are sufficiently grown to fend for themselves."

[3] See p. 303.

Or have they been acquired, like those of the Insects which pass through a chrysalis state? In other words:—Do the Pluteus and Bipinnaria larvæ represent the ancestry of Echinodermata, as the Nauplius larvæ most probably represent the ancestry of Crustacea? or are they forms which have been produced during the evolution of the class, like the maggot and chrysalis forms among some Insects? If the former answer is true, these metamorphoses, though they are by no means universal, must be regarded as normal in the class.

The question appears at present unanswerable. Peculiarities of these Metamorphoses.—We do not appear to have at present the means of answering this question. The subject is one of extraordinary difficulty. It appears impossible to suggest any explanation of the descent of an Echinoderm from a form resembling a Pluteus or a Bipinnaria; and it appears equally impossible to suggest any explanation of the acquisition of such metamorphoses by Echinoderms, supposing them not to be primary in the class. Among Insects, much of the metamorphosis is adaptive, and is to be, not perhaps explained by, but at least referred to, the different conditions of life of the larva and the perfect form; but this clue fails us with the Echinodermata, because they inhabit the ocean at all periods of their lives, and undergo no change of conditions to which their metamorphoses can be referred. It is true the same clue fails, and for the same reason, in tracing the development of the higher Crustacea out of Nauplius or Zoea larvæ. But the change which takes place in the process of metamorphosis is far greater in the Echinoderms than in the Crustacea, and is, in a great degree, different in kind. In the development of Müller's *Peneus*, by successive changes, out of its Nauplius larva, the animal acquires new eyes, new limbs, new segments, a carapace, and respiratory organs; but these are all developed externally, constituting additions to the organic apparatus with which it commenced its life; and there can be no more doubt of the identity of the animal through all its metamorphoses, than of

the identity of the man with the child. With the Echinoderm it is different; the mode of development, as we have mentioned, varies much, but the Sea-urchin is developed within the body of the Pluteus; and the young Echinoderm is mainly a new development, with only a part of the old structure, as it were, built into the new—that is to say, with none of the external organs and only part of the viscera of the larva appropriated by the mature form.

Differences of the Larvæ among themselves.—If the metamorphoses of the Echinodermata are primary, so that their larvæ represent the ancestors of the class, the larvæ, as well as the perfect forms, must have been much modified during the evolution of the class. This is shown by the important difference between Pluteus and Bipinnaria, whereof the former has a calcareous skeleton, which is wanting in the latter. Such modifications, however, do not appear specially improbable. Nor does the great variability of these metamorphoses appear to be a conclusive reason against thinking that they are primary. No variation, probably, is more easily effected than the substitution of direct for indirect development, and the consequent loss of metamorphosis, as in the cases of the *Hylodes* Tree-frog and the fresh-water Cray-fish;[1] and the same may have occurred in the Echinoderms of the Southern hemisphere.[2]

It is on the whole most probable that these Metamorphoses are primary.—It appears on the whole the most probable opinion that the metamorphoses of the Echinodermata are primary. The Echinodermata are a group which is very much detached from all others, but they have affinities with the lower worms, though mostly very unlike them in form; and the larval forms described above appear to strengthen the connexion with these, and also to point to a possible connexion with the Ctenophora, a lowly organized class of transparent marine swimming animals, allied to the Hydrozoa. Some of the Echinoderm larvæ have a very

[1] See pp. 281, 293. [2] See p. 313.

decided resemblance to some of the Ctenophora in external form, and in the ciliated bands by which they swim; but it would not be safe to lay much stress on this. If these metamorphoses are not primary but acquired, it appears a necessary inference that they must be adaptive; and there does not appear to be, in the course of the development of Echinoderms, any change of life and habits to which adaptive metamorphoses could be referred. But whether they are primary or acquired, these wonderful metamorphoses appear to be one of the greatest unsolved difficulties of evolution, and they obviously point to some law of life quite independent of natural selection.

Classes of Metamorphoses.—We have seen in the course of the present chapter, that metamorphoses may be distinguished in three ways. They may be primary or acquired; non-adaptive or adaptive; and progressive or retrogressive.

Primary and acquired Metamorphoses.—We call a metamorphosis a primary one when each successive stage represents an ancestral form. We call it an acquired one, when, on the contrary, some of the stages do not represent ancestral forms, but have been evolved, in the evolution of the species, later than the perfect form. Most metamorphoses are primary. There are none which can be distinguished as acquired, except those of the Insects which pass through a chrysalis state;[1] but if the conclusion is true which we have stated as the most probable respecting the Echinodermata, their metamorphoses have an intermediate character;—they are primary, but have important secondary characters, such as the skeleton of the Pluteus larva.[2] The *Pylidium* larva of *Lineus* is probably of this kind;—it is probably only a modification of the usual form of its class.[3]

Adaptive and non-adaptive Metamorphoses.—Some metamorphoses, as those of the higher Crustacea, are non-adaptive—that is to say, they seem incapable of being referred to any change in the conditions of life; and they appear to be due only to a

[1] See p. 303. [2] See p. 310. [3] See p. 311.

vital impulse. Others are adaptive, as those of Batrachians and of Insects.

Progressive and retrogressive Metamorphoses.—Most metamorphoses are progressive, as those of Batrachia, of Insects, of the higher Crustacea, and of the Echinodermata; but some are retrogressive, as in the cases of those Nauplius larvæ which are transformed into Barnacles and into worm-like parasites.

Combination of these characters.—These characters appear to be capable of being combined in any way, except that acquired metamorphoses are always adaptive, and retrogressive metamorphoses are probably always adaptive; but the converse of these propositions does not hold; the adaptive metamorphosis of the Frog is primary, and the retrogressive metamorphosis of Barnacles is also primary.

Value of larval characters in Classification.—Fundamental similarity of larval or embryonic character is, as we have seen, a certain proof of true affinity, and consequently may be of great importance in classification. The connexion of such forms as *Lepas*, *Lernœocera*, and *Sacculina*, with the Crustacea, is proved chiefly, if not exclusively, by their larvæ. In general, however, larval characters appear to be of much less importance in classification than those of the mature form. This may be partly due to their great variability, or rather instability, in consequence of metamorphoses being easily lost, through the dropping out of stages of development; and this kind of change does not in any degree affect the affinities of a species; thus *Hylodes Martinicensis* is not the less a frog because it does not begin its life as a tadpole.

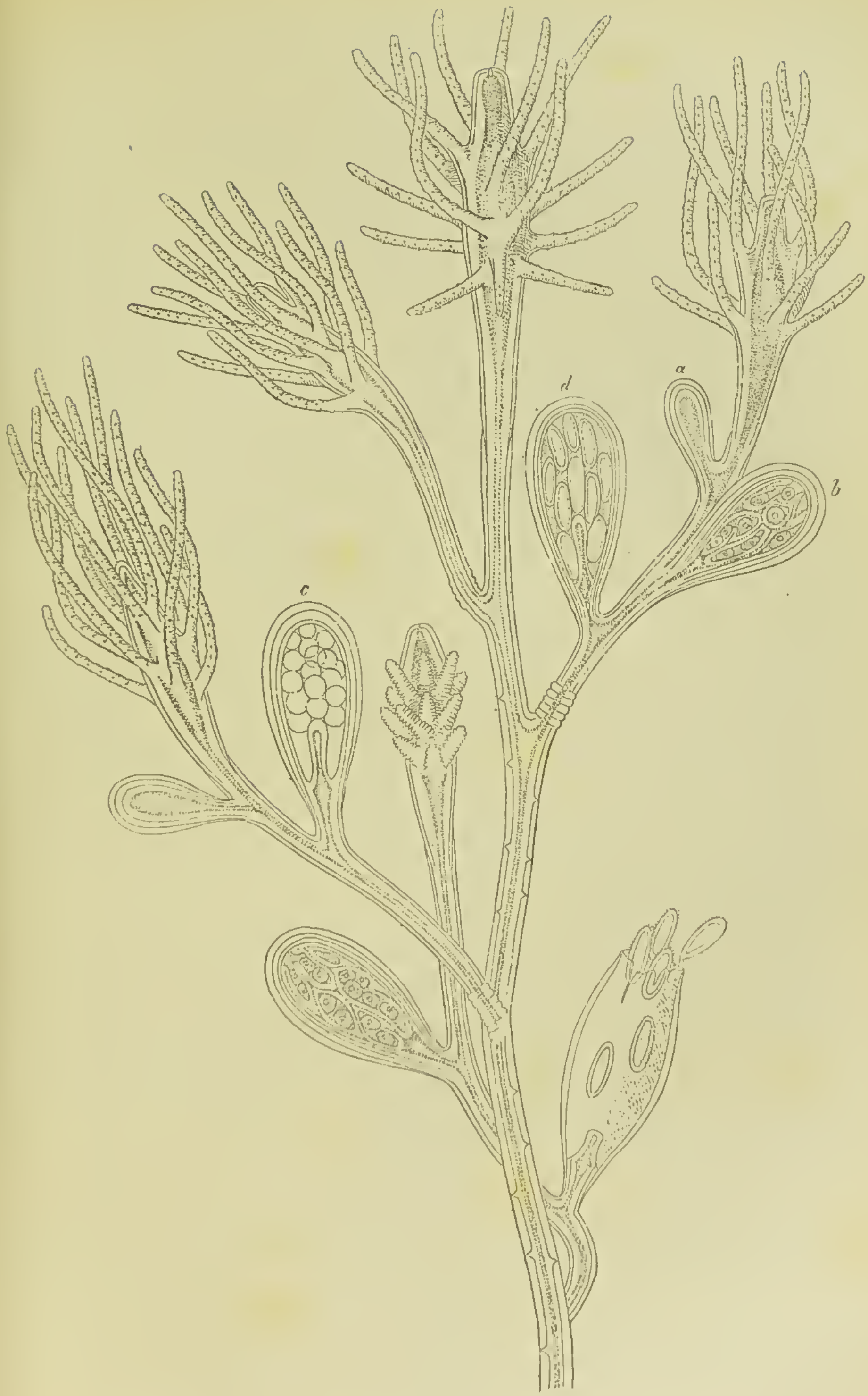
Metagenesis: Hydrozoa, Flowers and Ferns.—The facts of Metagenesis, or alteration of generations, throw as much light on the origin of animal forms as do those of Metamorphosis. Metagenesis is very common in that most interesting class the Hydrozoa;—hydra-like forms produce Medusæ, and Medusæ in turn produce hydra-like forms. But in this, as in

all metagenesis, not only the generations are unlike, but they are produced by different processes, one of which is sexual, while the other is non-sexual and by budding. It is well known that flowers are sexual organs; and if the flowers of a plant, after being produced by budding, were to become detached before maturing their seed, this would be a case of metagenesis—the two alternate generations being the plant with its leaves producing the flower non-sexually, and the flower producing young plants by seed sexually. This is what actually occurs among Ferns: the spore which is matured at the back of the leaf is a bud produced non-sexually, and from it, after it is detached and falls on the ground, is developed a form resembling *Marchantia*, one of the Liverworts, an order connecting Mosses with Lichens; and the Marchantia-like form produces, by a sexual process, the germ that gives origin to the Fern.

The fresh-water Hydra.—To resume the subject of the Hydrozoa. The fresh-water *Hydra* is the simplest member of the class;[1] it is shaped like a leech, but with a ring of tentacles round the mouth, and has the entire interior of its body occupied by a stomach. It thus resembles the cut-off finger of a glove, with a fringe of tentacles round the open end. It is capable either of crawling about or of fixing itself, like a leech, by the tail end. It propagates in two ways;—non-sexually, by budding off, from its sides, young *hydræ*, which become detached and crawl away;—and sexually, maturing the generative products in temporary enlargements of the wall of the body.

The compound Hydrozoa.—The *Hydra* does not become a compound animal, because the young *hydræ* which are produced by budding do not continue to be attached. But in the compound Hydrozoa, which are by far the greater part of the class, the budding process does not produce distinct animals attaining

[1] Excepting an animal which may be described as a *Hydra* without tentacles, inhabiting marine mud, and called by Greef, *Protohydra Leuckarti*. This, however, has not been found in a sexually mature state, and may possibly be a larva, destined to be transformed into some much higher form.



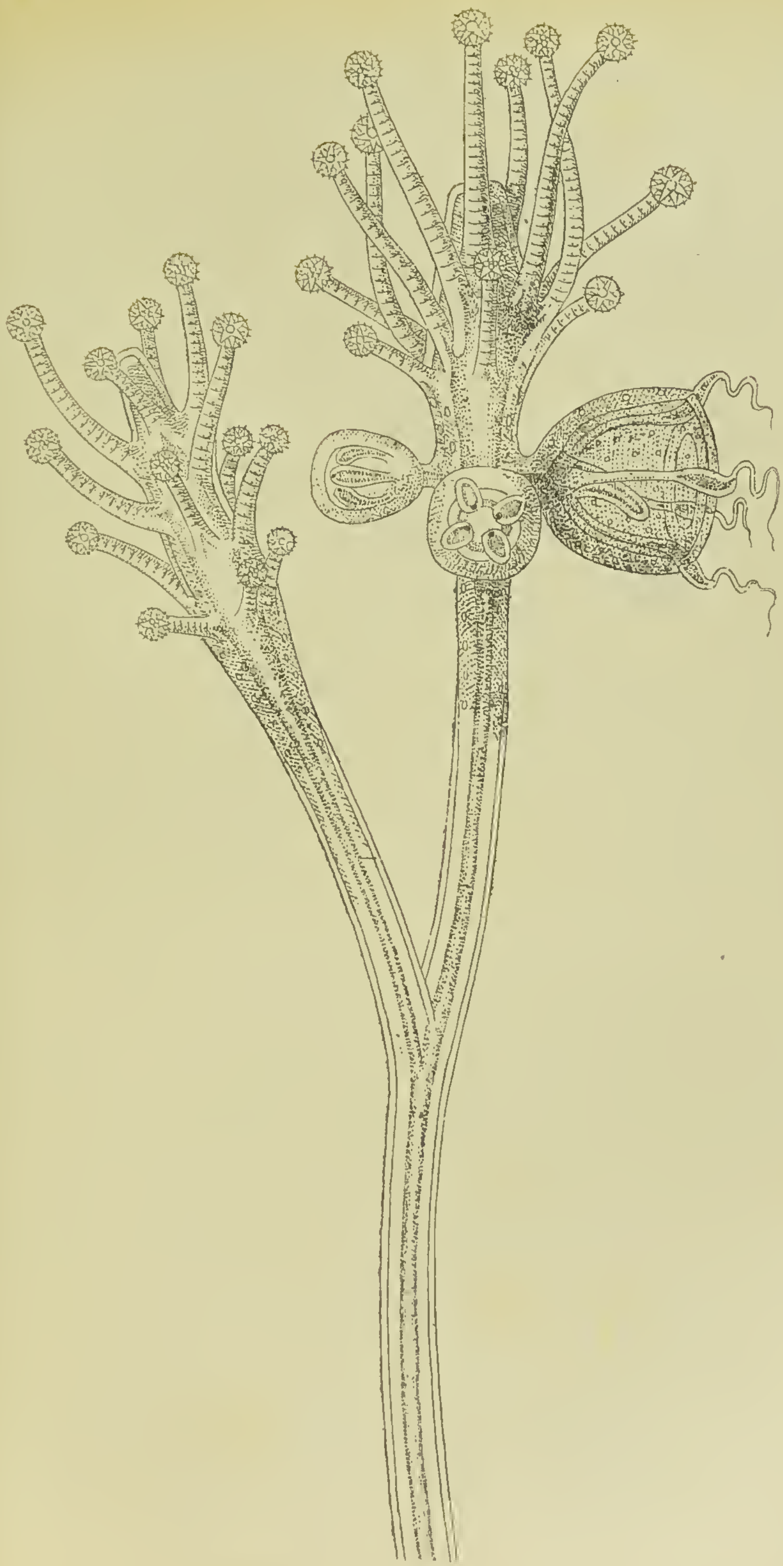
Cordylophora lacustris. Portion of female colony. From Allman's *Gymnoblastic Hydroids,* published by the Ray Society.

to individuality, but "zooids" remaining in organic connexion with the parent.[1] The relation of the zooids to each other is thus like that of the leaves of the same plant; and as in plants the stem does not belong to any particular leaf, so among the compound Hydrozoa there is generally a stem that does not belong to any particular zooid. In accordance with a tendency which is too general in the organic world to need any special explanation in particular cases, a "physiological division of labour" is set up between the zooids;—some of them assume the nutritive function, and others the reproductive, with corresponding differences of form and structure. The nutritive zooids are called by Allman "hydranths," from their resemblance to Hydræ. The relation between the hydranths and the reproductive zooids is almost exactly similar to that between the leaves and the flowers of a plant. The analogy is not complete, only because a reproductive zooid is homologous with a single hydranth, while a flower is homologous, not with a single leaf, but with the entire product of a leaf-bud. In the illustration on page 319, the hydranths are recognised by their tentacles, which are used as arms to seize the animal's food, and also probably serve as respiratory organs; while the ova are seen escaping and swimming away from the most mature of the reproductive zooids.

The reproductive zooids of *Cordylophora*, here figured, have little more appearance of independent life than the temporary enlargements of the body of *Hydra* in which the generative products are matured, and differ from them chiefly in being produced on a stem which is common to a number of zooids, instead of on the body of a hydranth.

Medusa form of reproductive Zooid. Syncoryne.—But in other compound Hydrozoa, the reproductive zooids acquire

[1] By the word "zooid" is meant something intermediate in character between a distinct individual and one of the organs of an organism. It appears to have been invented in order to evade the difficulty of deciding when to speak of an animal in the sense of an individual animal.



Syncoryne frutescens. From Allman's *Gymnoblastic Hydroids.*

mouths and tentacles, so as to have a life as independent as that of the nutritive zooids; and in many cases they become detached and swim away before attaining maturity. In this state they are called Medusæ or jelly-fish; and the single Medusa often grows very much larger than the stock from which it was detached. The illustration on the preceding page shows a branch of *Syncoryne* bearing both hydranths and reproductive zooids, the latter of which are in different stages of development;—that on the opposite page shows one of the reproductive zooids shortly after its separation as a Medusa.

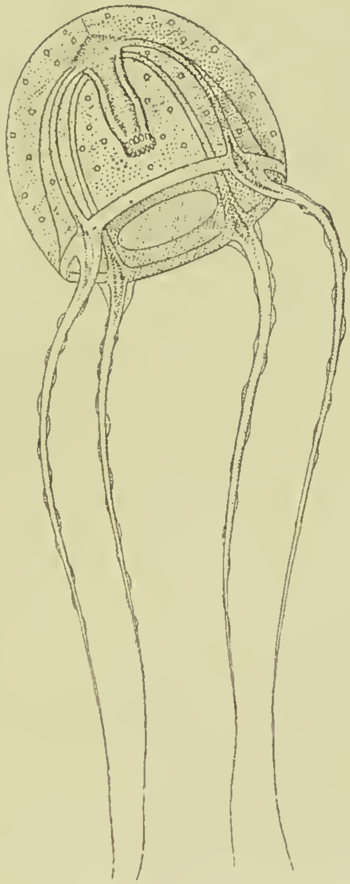
Such a species as this presents a perfect example of metagenesis. The compound Hydrozoon produces Medusæ non-sexually by budding, and the Medusa reproduces the compound Hydrozoon sexually, from the egg. In the order Hydroida, to which the fresh-water *Hydra* belongs, there does not appear to be any proved instance of a Medusa being developed directly from the egg;—it is not at all improbable that there may be such instances, but so far as is yet known with certainty, there is no Medusa development in this order except from buds as already described. But some of the Medusæ of this order produce Medusæ by budding. Prof. Hincks says:—

Prof. Hincks on the Budding of Medusæ from Medusæ.—"Some of the Medusæ produce buds which assume the form of the parent, and probably repeat its life. They are borne in various positions: in some cases springing from the bulbous base of the tentacles or from the tentacle itself: in others from the base of the digestive sac: and in one instance, at least, from the margin of the bell between the tentacles. And these buds may produce other buds, so that two generations may hang from the body of the primary zooid before its separation from the parent stock." [1]

Parallel fact in Ivy.—Thus the Medusæ of these species produce Medusæ by budding, but produce hydranths from the egg.

[1] "The Hydroid Medusæ," by the Rev. Thomas Hincks. *Popular Science Review*, 1872, p. 345.

It will be remembered that the relation of the Medusa to the hydranth is similar to that of the flower to the leaf, or rather that of the flower-bud to the leaf-bud ;—and this fact respecting the budding of Medusæ may be compared to the following fact respecting the flowers of the ivy :—It is well known that "when



Medusa of *Syncoryne frutescens*, shortly after liberation. From Allman's *Gymnoblastic Hydroids*.

the ivy is about to produce flowers it assumes an erect bushy habit, and its leaves alter in form. If such branches are taken off and propagated [by cuttings, not by seed] the characteristic form remains, as in what are called tree ivies."[1] Thus the

[1] Dr. Masters on "Bud-variation." *Popular Science Review*, vol. xi., 1872, p. 248.

flowering branch of the ivy, like the Medusa, produces branches like itself when propagated by cuttings, which are physiologically analogous to buds, while it produces by the sexual process of flowering and seeding, not a plant like itself, but a plant like the stock on which it grew.

Medusæ produced directly from the egg.—To return to the subject of the Hydrozoa :—Among the Discophora, an order differing in some important characters from the Hydroida,[1] there are some genera, *e.g. Pelagia,* in which the Medusa produces Medusæ directly from the egg, and there is no fixed or hydraform zooid at all.

The Hydrozoa thus present the following series :—

Gradation of the reproductive process in Hydrozoa.—1. *Hydra,* in which there are no distinct reproductive zooids, but the ordinary nutritive zooids develop temporary reproductive organs.[2] In this genus there is no approach to metagenesis, except in so far that sexual reproduction occurs, not in every generation, but at intervals of some generations ;—propagation in the intervening generations being non-sexual, and by the process of budding.

2. Such forms as *Cordylophora,* in which there are distinct nutritive zooids, but they have no organization fitting them for an independent life. This is an approach to metagenesis.

[1] The chief anatomical distinction between the Hydroida and the Discophora appears to be that in the Hydroida the generative products discharge exteriorly ; in the Discophora they discharge interiorly, and escape by the mouth. There is also this difference, which probably stands in close connexion with the former, that in the Hydroida the Medusæ, in those species where they are produced, are budded off at the side of the stem ; in the Discophora they are detached from the summit, or mouth end, of a nutritive zooid.

[2] Some writers call the temporary reproductive organs of *Hydra* distinct zooids. It is true, as we shall see when we come to the details of the gradation, that the reproductive organs of *Hydra* are homologous with the reproductive zooids of *Cordylophora, Syncoryne,* and other compound Hydrozoa ; but if they are regarded simply by themselves no naturalist would call them zooids. The question is perhaps only a verbal one.

3. Such forms as *Syncoryne*, in which the reproductive zooids become detached and lead an independent life as Medusæ. This is perfect metagenesis.

4. Such forms as *Pelagia*, in which Medusæ are produced direct from the egg, and the Medusa is the only form. Here metagenesis has been lost.

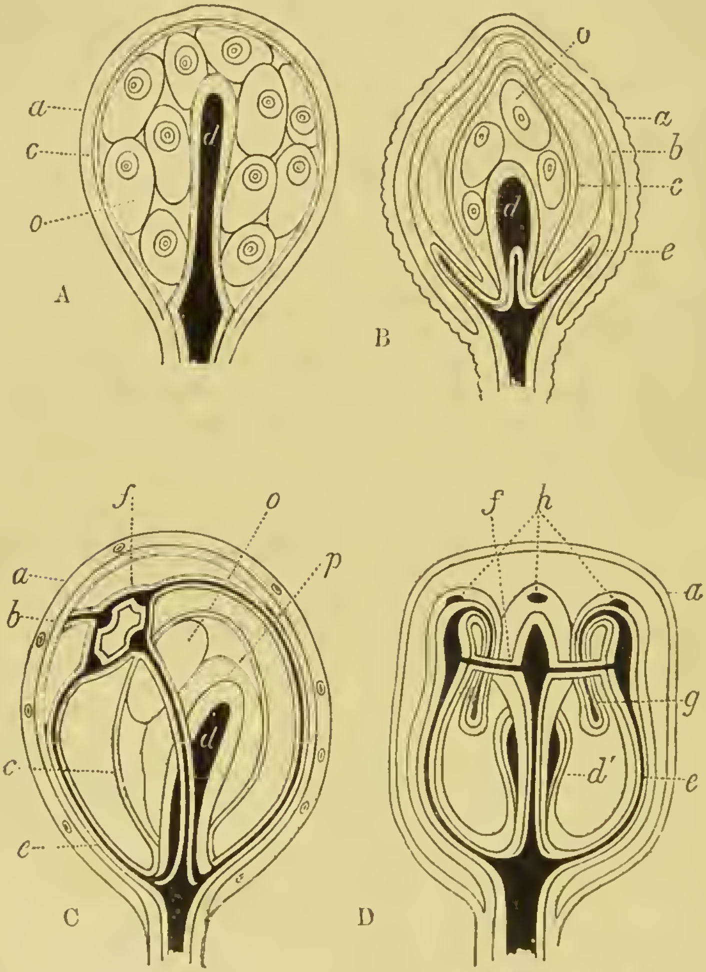
Believers in evolution cannot doubt that these forms have been successively evolved, one from the other, in the order here enumerated. I do not mean that *Pelagia*, which is a Discophore, can be descended from *Syncoryne*, which is a Hydroid. The anatomical differences forbid this supposition. But the development of Medusæ out of *Hydra*-like sessile forms may very well have occurred in these two orders separately, and the above enumeration shows the kind of gradation which has probably occurred in both.

Details of the gradation.—From the reproductive system of *Hydra*, with no separate reproductive zooids, to that of such a form as *Syncoryne* with its Medusa, there is an almost perfect gradation, which is shown in the diagrams on the following page.

Hydractinia echinata.—First, we have *Hydractinia*, the reproductive zooid of which, here shown in section, is almost exactly similar to that of *Cordylophora*, whereof the external appearance has been shown in a previous illustration. It will be seen that this is a mere sac with a central spadix (so called by Allman), and ova maturing between the spadix and the walls of the sac.

Garveia nutans.—*Garveia* presents the next stage of development. In all the compound Hydroida there is a cavity in the centre of the common stem, which sends tubular prolongations to all the zooids, whether nutritive or reproductive; and in *Garveia* this tube is seen sending four radiating branches, *c* (one of the four being concealed), into the walls of the sac; but they remain closed at the upper or distal ends.

Tubularia indivisa.—In *Tubularia* these "radiating canals" are no longer closed, but open into a "circular canal" shown at



Diagrams of reproductive zooids. From Allman's *Gymnoblastic Hydroids*, p. 44.
A, *Hydractinia echinata;* B, *Garveia nutans;* C, *Tubularia indivisa;* D, *Syncoryne eximia.*
a, ectotheca; *b*, mesotheca; *c*, endotheca; *d*, spadix; *d′*, manubrium; *e*, radiating canals; *f*, circular canal; *g*, marginal tentacles; *h*, ocelli; *o*, ova; *p*, ovarian plasma in *Tubularia*.[1]

f; and there is an opening in the centre of the circular space surrounded by the canal, at the summit of the zoid, which we

[1] It will be observed that these are mere diagrams, unlike the rest of the illustrations to this chapter, which at least attempt to represent the forms as they appear.

can no longer call a mere sac. The radiating canals are homologous with the tubes which are continued into the tentacles of the nutritive zooids, but the circular canal is characteristic of the Hydroid Medusæ, and is not represented in the nutritive zooids. The reproductive zooid of this Tubularia has thus an almost perfect Medusa structure; and yet it is not a Medusa, for it cannot swim; and it does not become detached, but matures its products, like a flower, on the stem.

Syncoryne eximia.—Lastly, the reproductive zooid of *Syncoryne* breaks off, and swims away as a perfect Medusa. The diagram represents it before detachment, and with the marginal tentacles, *g*, doubled downwards and inwards.[1]

Structure of Hydroid Medusæ.—A Hydroid Medusa, as may be understood from the illustration on p. 323, is a very simple organism, resembling a *Hydra*, but with a circular membrane surrounding it, shaped like an umbrella, and attached to the proximal or tail end—the Hydra-like part being in the position of the stick of the umbrella. The radiating and circular canals are excavated in the substance of the umbrella, which is the swimming organ.

Homology of the Medusa.—An examination of the diagrams will make it obvious that the "manubrium," *d*, or Hydra-like organ of the Medusa of *Syncoryne* shown at D, is homologous with the *spadix*, *d*, of the ovarian sac which constitutes the reproductive zooid of *Hydractinia* shown at A; and a believer in evolution can scarcely doubt that the descent of all Medusa forms has been along such a line of descent and by such transitions as are here indicated. The changes from A to D are no doubt great; they may be thus enumerated :—

In *Hydractinia* there are two membranes, the ectotheca and the

[1] The Medusa of a different species of *Syncoryne* is represented after detachment on p. 323. It must be observed that in the diagram on p. 326 the zooid is drawn attached, and with its mouth up; that on p. 323 has its mouth down, being the habitual position of Medusæ while swimming.

endotheca, or outer and inner covering, surrounding the ovarian sac. In the other forms a membrane called the mesotheca is developed between the two, and in its substance first the radiating and afterwards the circular canals are excavated. Next, the ectotheca and mesotheca are perforated, and expand, while the endotheca shrinks round the spadix. In the most typically-constituted Medusæ, the wall of the manubrium, between the spadix and the ectotheca, continues to be the place where the ova are matured. By the perforation of the summit of the zooid and the expansion of the mesotheca, the zooid is changed from a closed sac into an open cup, and the Medusa form is attained. At the same time, a mouth is formed at the summit of the manubrium, and a stomach, or body-cavity, is hollowed out in its substance, so that it can feed and live alone. (These last are not shown in the diagrams.) The hollowing out of the stomach is not so great a change as might appear, for in the Hydrozoa generally the central cavity of the common stem sends out a tubular branch to every hydranth, and it is probable that a similar tubular branch runs up into the spadix of such a reproductive zooid as that of *Hydractinia*, in its youngest state at least.

Homology between the Hydranth and the Medusa.—When the homology between the hydranth and the Medusa was once pointed out, there could not be much doubt of its reality. It has, however, received further confirmation by Prof. Allman's discovery of a compound Hydrozoon whereof all the zooids have the character of Medusæ. It has been found on the southern shores of France, and in connexion with a sponge, on which it appears to be parasitic. Prof. Allman calls it *Stephanoscyphus*. I quote part of his description.[1]

Prof. Allman on Stephanoscyphus.—"The chitinous tubes and their contents are united by a common tubular plexus, which

[1] From *Nature* of 30th July, 1874.

lies towards the base of the sponge, and they thus constitute a composite colony of zooids. The tubes, towards their free extremities, where they open on the surface of the sponge, become much increased in width; and here their contents become developed into a very remarkable body, which has the power of extending itself beyond the orifice of the tube, and of again withdrawing itself far into the interior cavity, exactly like the hydranth or polypite of a Campanularian Hydroid in its hydrotheca.[1] When extended, it displays, around the margin of a wide terminal orifice, its beautiful crown of tentacles; but when withdrawn into the interior of the cup-like receptacle, the tentacles are greatly contracted, and thrown back into the cavity of its body. Its general appearance, indeed, is very like that of a Campanularian hydranth, and a careful examination is needed in order to show that it possesses all the essential characters, not of a hydranth but of a Medusa. It has a circular canal surrounding the terminal orifice and supporting the tentacular crown, and it has four symmetrically-disposed longitudinal canals[2] extending from the circular canal backwards in the walls of the body. . . . *Stephanoscyphus* may then be regarded as a compound Hydrozoon, whose zooids are included in cup-like receptacles resembling the hydrothecæ of the calyptoblastic Hydroids; but these zooids, instead of being constructed like the hydranths of a Hydroid, are formed on the plan of a Medusa. It has plainly very decided affinities with the Hydroida, but is nevertheless removed from these by a distance at least as great as that which separates them from the Siphonophora. It thus becomes the type of a new hydrozoal order, for which I propose the name of Thecomedusæ."

If a species of plant were discovered bearing all flowers and

[1] The hydrotheca is a kind of calyx, formed of chitinous or horny substance, which in the Campanularians surrounds the flower-like hydranth.

[2] These are what in the foregoing paragraphs have been called the radial canals. They radiate from the base to the edges of the expanded flower-like Medusa; but when it contracts its tentacles and closes its mouth, so as to resemble an unopened flower, their position becomes similar to that of the lines of longitude on a globe. This will become obvious by referring to the diagrams on p. 326.

no leaves, this might be compared to such a Hydrozoon as this, bearing all Medusæ and no hydranths. It does not appear, however, that the Medusæ of *Stephanoscyphus* ever become detached.

Argument against Darwinism from these facts.—An argument against the Darwinian theory appears to be afforded by these facts of Medusa development, similar to that which we have already based on those of Crustacean development.[1] Natural selection will account only for changes which are immediately beneficial, not for those which are to be beneficial to a race to be hereafter evolved; and consequently it will not account for Medusa development in species where the Medusa is never perfectly developed, and always remains attached to the stem as a mere medusoid bud. Were it possible for the Medusa or any other freely swimming form of reproductive zooid to be evolved all at once by a single variation, it would probably be preserved by natural selection, in consequence of the enormous advantage it would give to the race in respect of the means of wide dispersal—an advantage similar in kind to that possessed by plants with winged seeds, though probably far greater in degree. But it is impossible to see what advantage can result to a Hydroid species from mere *approach* in its reproductive zooid to Medusa structure, without attaining the purpose of Medusa structure, which is a freely swimming reproductive zooid; yet such approach appears to have gone on through an unknown and perhaps an immense number of generations, including many transitions from species to species, during which the Medusa structure was in process of being perfected; and this must in all probability have taken place on several distinct lines of descent, inasmuch as Medusa structure is not universal in any sub-order of the Hydroida, but is common in different sub-orders and families having to each other classificatory relations which exclude the supposition that the Medusa structure

[1] See p. 293 *et seq.*

can have a common origin for all. This appears to be a case of "independent similarity" of structure produced and perfected on several distinct lines of descent, in a way which excludes the action of natural selection.

Slightness of the ultimate transition.—The final transition from the fixed to the free-swimming reproductive zooid is very slight. Allman states [1] that "among the Medusæ must be included certain comparatively rare instances in which the medusiform zooid, though having its natatory organ well developed, remains, from some unknown cause, attached to the stem, and attains to sexual maturity without becoming free. It is capable, however, when accidentally detached, of swimming by the systole and diastole of a true natatory umbrella, and cannot, therefore, be placed in a different catagory from that of the essentially free Medusa." Agassiz states [2] that the reproductive zooid of *Coryne mirabilis*, when produced early in the year, swims away as a Medusa; but when produced later he has seen it mature its generative products without leaving the stem. Allman thinks the species may be different; but when we see, according to his own statement, that some reproductive zooids are able to swim when detached, though they do not detach themselves, it seems necessary to believe that the free-swimming life is the normal one, and the permanently attached state only accidental. In other words, it is easier to believe that a normally free zooid is able to live and grow to maturity without becoming free, than that a normally fixed zooid is fit for a free life when accidentally detached. If it is true that in the same species some Medusæ swim away while others remain permanently attached, this is much less wonderful than the fact that many plants produce two kinds of flowers, the one open and adapted for fertilization by insects, the other closed, or what Darwin calls "cleistogene," and adapted only for self-fertilization.

It is certain, however, that the distinction between perfect free Medusæ and permanently attached medusoids is so slight

[1] Allman's *Gymnoblastic Hydroids*, p. 29. [2] *Ibid.* p. 30.

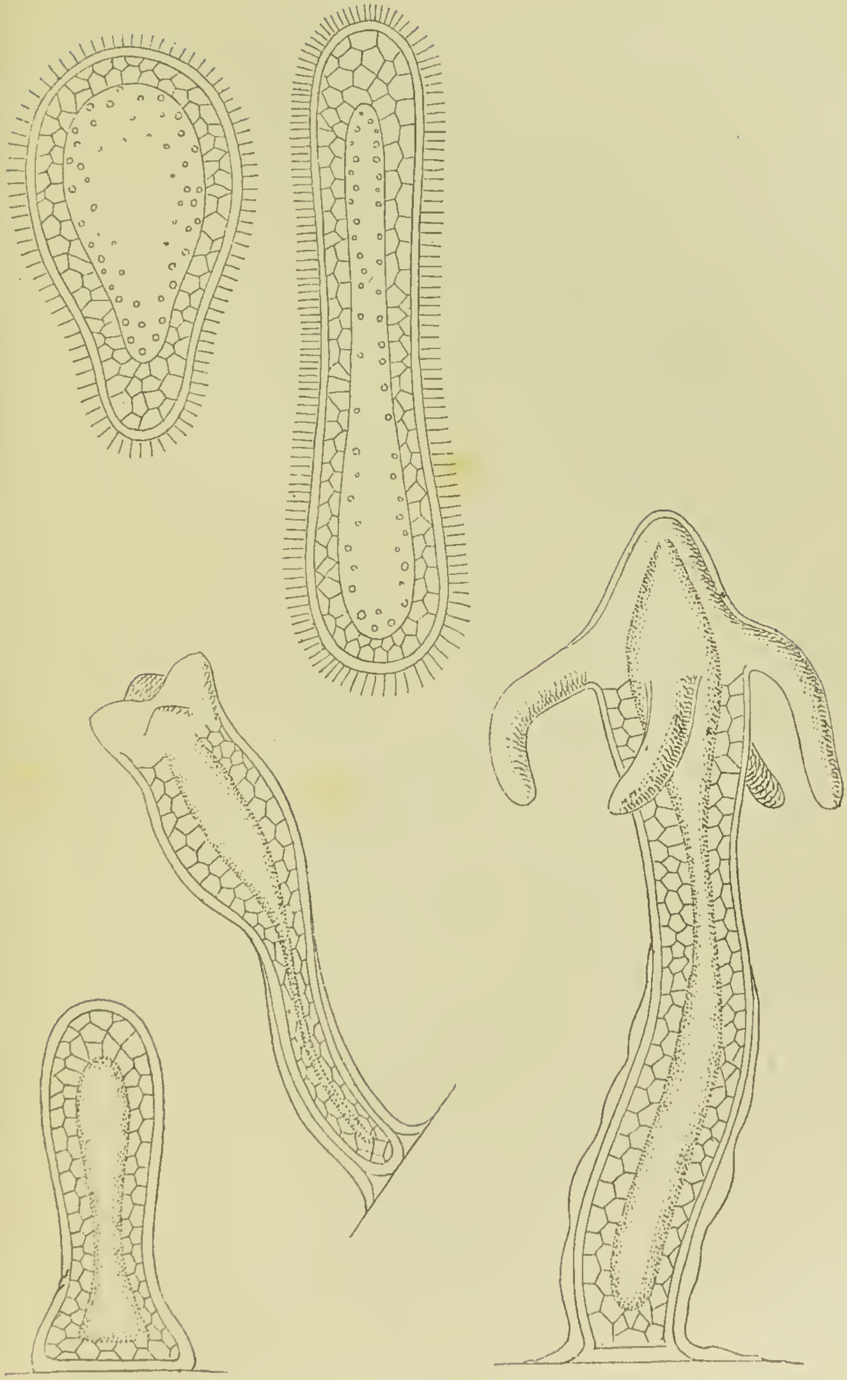
that both are met with in the same genus. The eminent Norwegian naturalist, Sars, states that in the genus *Corymorpha*, five of the known species produce Medusæ, which swim away before they produce the generative products; *Corymorpha glacialis*, on the contrary, produces only what he calls imperfect sessile (or permanently attached) Medusæ; and there are similar instances in other genera. The detached and the sessile forms are similar in development and in all respects, up to the point where the sessile ones are arrested in development.[1]

Difficulty of classifying the Hydroida: Its reason.—Allman says[2]:—"The classification of the Hydroida would be comparatively easy if generically identical medusoids always arose from generically identical polypoids (or hydranths), and the converse. But this is not the case; two phenomena break the uniformity; the association of similar reproductive zooids with dissimilar polypoids, and the association of dissimilar reproductive zooids with similar polypoids."

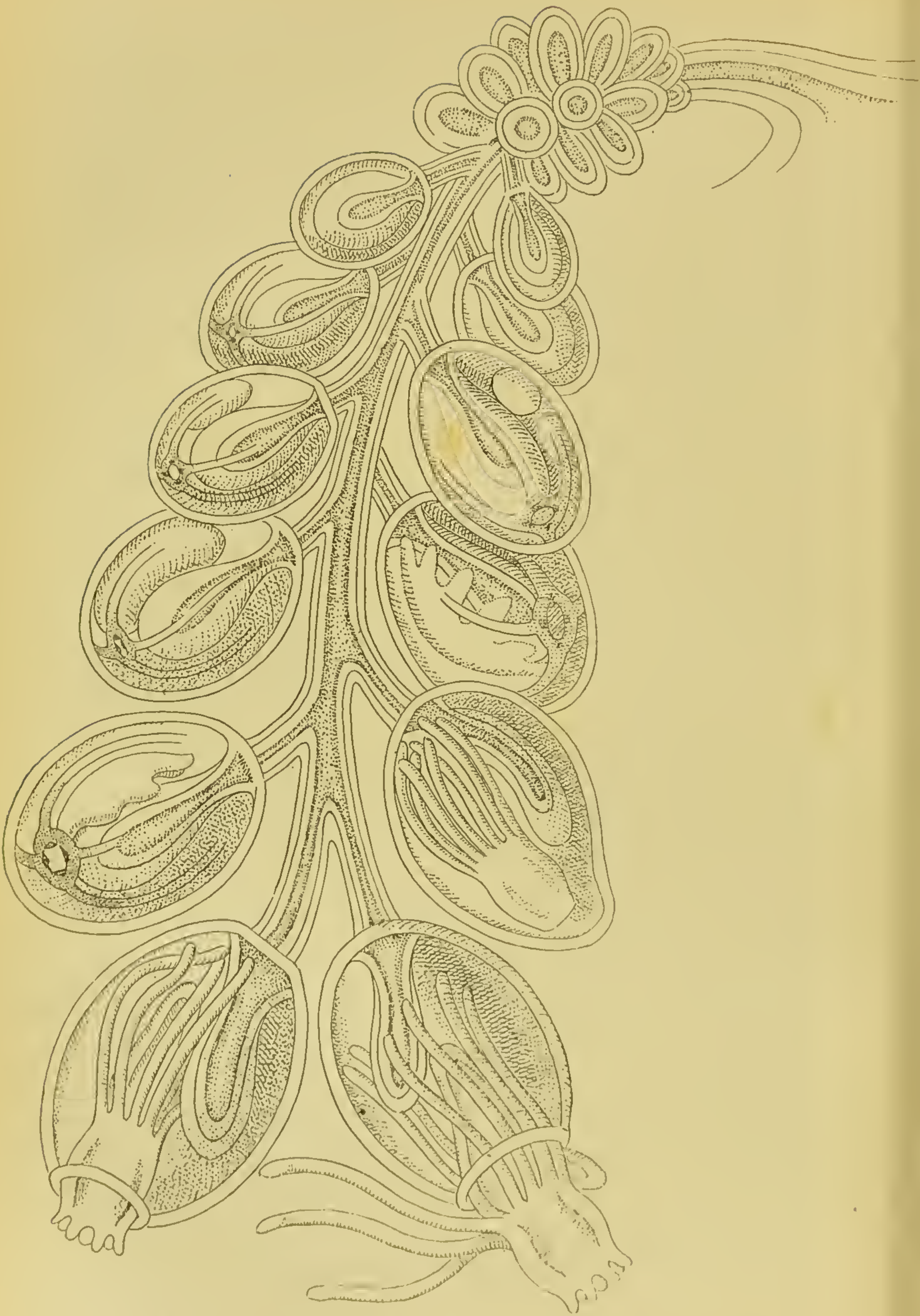
Probably resemblance either of Hydranths or Medusæ proves true affinity.—It seems probable that as among Insects and Crustacea true genetic affinity may be inferred from resemblance in either the larva or the perfect form, so among Hydrozoa true affinity may be inferred from resemblance in either the hydranth or the Medusa; but in view of the great number of "independent similarities" not due to community of origin, in classes much better known and less difficult than the Hydrozoa, it would be unsafe to assume the truth of this rule in particular cases. In the present state of knowledge on the subject, any attempt at a detailed classification of the Hydrozoa is made under somewhat the same kind of disadvantage as if we were to endeavour to classify an insect order, whereof we knew a number of larvæ and a number of mature forms, without

[1] Sars on "Corymorpha," *Annals of Natural History*, Nov. 1861, p. 358.

[2] "Construction and Limitation of Genera among the Hydroida," *Annals of Natural History*, May, 1864.



Planula development of *Cordylophora lacustris.* Much magnified. From Allman's *Gymnoblastic Hydroids.*



Tubularia indivisa. Raceme-like cluster of gonophores, magnified, from a female colony, with actinula escaping from one of them. From Allman's *Gymnoblastic Hydroids.*

knowing, in a large proportion of the cases, which larvæ and which mature forms belonged to each other.

Planula development from the egg.—We have not yet spoken of the earlier development of the Hydrozoa. In this we have an interesting case of the loss of a stage in metamorphosis. In the mode of development which appears to be normal to the class, the egg is first changed into a ciliated germ, and this into a ciliated zooid of an elongated form, still freely swimming, called a "planula." This afterwards becomes fixed by one end, loses its cilia, grows, developes tentacles, and becomes a hydranth. All these stages are represented in the illustration on p. 333, as observed in *Cordylophora lacustris.*

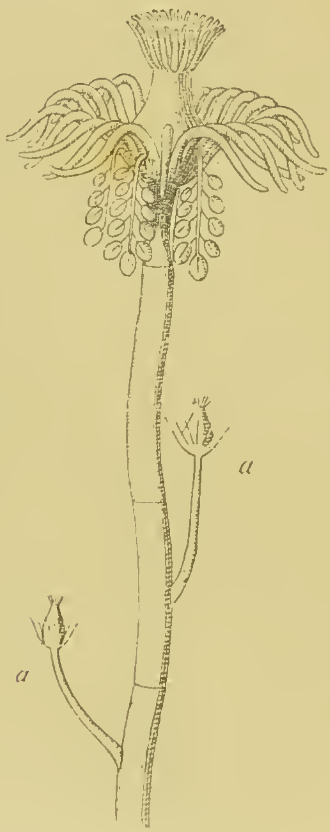
Actinula development.—This is the usual mode of development from the egg among the Hydrozoa, but in some species the first stages are left out, and the egg developes at once into a diminutive hydranth which swims freely at first but soon becomes rooted. This form is called an "actinula," from its resemblance to an *actinia* or sea-anemone. The illustration opposite shows a raceme of the gonophores or reproductive zooids of *Tubularia indivisa,* with an actinula escaping from one of them. It will be seen that the actinula has some degree of external resemblance to a Medusa; there is however no true analogy, because they occur in quite different parts of the cycle of transformation and metagenesis; the actinula is the immediate product of the egg, and the Medusa is the producer of the egg.

Racemes of reproductive Zooids in Tubularia.—In the compound Hydrozoa, as in plants, the oldest buds are in some species at the proximal or root end of the branch; in others, as here, at the summit.

We also show, on the following page, a hydranth of the species, with the raceme-like cluster hanging between the tentacles.

Summary.—In the present chapter we have arrived at two important conclusions.

First, we have seen that the process of metamorphosis and metagenesis probably represents the process of the development of the species, and that larval forms probably represent ancestral forms. We leave out of consideration for the present



Hydranth of *Tabularia indivisa*, natural size. From Allman's *Gymnoblastic Hydroids*.

the metamorphoses of the Echinodermata, which are not clearly explained; and also those of Insects, which are complicated threefold by the reversion of the larva in some orders to a worm-like type, by the acquisition of a water-breathing apparatus in some larvæ, and by the introduction of a chrysalis stage of development, which must have been acquired during

evolution, because it cannot represent any possible mature form. Omitting these, there are in nature three series which appear to represent before our eyes the process whereby existing forms have been evolved. These are the metamorphoses of the Batrachia, the metamorphoses of the Crustracea, and the metagenesis of the Hydrozoa.

Developmental Series of Batrachia.—The first of these series is as follows:—

1. Water-breathing Vertebrates (Fishes) producing their like.
2. Water-breathing Vertebrates (Tadpoles) developing into air-breathers, which again produce water-breathing Tadpoles from their eggs.
3. Air-breathing Vertebrates (*Hylodes Martinicensis* among Batrachians, and all the higher Vertebrate classes) producing their like.

Developmental Series of Crustacea.—The second series is as follows:—

1. Nauplius producing its like. There is no direct evidence of the existence of this, either now or formerly, but the *Cyclops* is comparatively near to it, as is indicated by the median eye.[1]
2. Nauplius developing into a Zoea, thence into a Mysis, and thence into the mature Malacostracan form of *Peneus*, which again produces Nauplii from the egg.
3. Malacostracans developed by the same process as Müller's *Peneus*, except that they leave out the Nauplius stage and leave the egg as Zoeas. Such are most Crabs.
4. Malacostracans, like the Lobster, which leaves out the Nauplius and Zoea stages, and begins as a Mysis.
5. Malacostracans like the fresh-water Crayfish, which is developed directly from the egg without metamorphosis.

Developmental Series of Hydrozoa.—The third series is as follows. It is to be observed that the hydranth, which is

[1] See p. 288.

non-sexual, corresponds to the larva, which is also non-sexual; and the sexual Medusa corresponds to the sexually mature form of animals that undergo metamorphosis.

1. Fresh-water *Hydra,* which does not produce distinct reproductive zooids.

2. Forms like *Cordylophora* and *Hydractinia,*[1] with distinct reproductive zooids, which however have no power of independent life.

3. The transition proceeds through species with reproductive zooids like those of *Garveia,* and

4. *Tubularia,* to

5. *Syncoryne,* whereof the reproductive zooid becomes fitted for an independent life, and swims away as a Medusa.

6. Forms like *Pelagia* among the Discophora, and probably, though not certainly, some members of the Hydroida, where the Medusa is produced directly from the egg, and metagenesis has been lost.

Argument from these facts against Darwinism.—The second conclusion to which the survey of these facts has brought us, is that many of these transformations, especially among the Crustacea and the Hydrozoa, and we may probably add the Echinodermata, do not consist in adaptations to any new or special mode of life, and consequently cannot be accounted for by the Darwinian or any similar theory, but must be due to a formative impulse impressed on living matter at the beginning.

[1] See pp. 319 and 325.

CHAPTER XVIII.

STRUCTURE IN ANTICIPATION OF FUNCTION.

THE subject of the present chapter has been already commenced in the preceding, where we spoke of the approach to Medusa structure through a series of species in the Hydroid order.

Darwin and Spencer ascribe all Organic Characters to Self-adaptation and Variations preserved chiefly by Natural Selection.—According to the biological philosophy whereof Darwin and Spencer are the exponents, there are but two possible kinds of cause for any vital function or any morphological character. These may be described with extreme brevity, as, firstly, self-adaptation, effected according to the laws of habit; and secondly, spontaneous variations, produced according to unknown laws, but probably by the agency of external circumstances, and preserved, so as to become the characters of species and of classes, chiefly, though not exclusively,[1] by natural selection, ensuring the survival of the fittest. Both of these agencies accumulate by inheritance, through successive generations, to an indefinite extent.

There is no doubt that these are real agencies, and that their agency is co-extensive with life. The purpose of the present work, however, is to show that these, though universally acting, do not act alone; and that Intelligence is as much an ultimate fact as Habit.

[1] For Darwin's admission that natural selection is not the sole cause of the fixation of characters, see p. 221 *et seq.*

These agencies are Unintelligent and incapable of Foresight. If there is Foresight in organic development, there must be Intelligence.—These two agencies, which we call self-adaptation and natural selection, though acting on living things and through the vital forces, yet act mechanically; and moreover they are unintelligent, and therefore incapable of foresight. Even if they are sufficient, which I maintain they are not, to account for the utmost elaborateness of development and exactness of adaptation, it is evident that they can account only for such perfection as is needed for the actual life of the individual; they cannot possibly account for any development which is not useful at the time when it occurs, but is made in anticipation of being useful either at a future period of the organism's existence, or in a future generation. Habit, which is the acting power in the process of self-adaptation, cannot fit an organism for a life on which it has not yet entered; and natural selection can only select what is *immediately* useful. If it can be certainly shown in a single instance, that the formative agencies have acted with reference, not to the then existing but to an anticipated state of things, this will amount to conclusive proof that there must be a formative agency at work which cannot be resolved into self-adaptation and natural selection, and which must be intelligent. "Darwin himself has taken care to impress on us that natural selection has no power to produce absolute perfection, but only relative perfection,—no power to advance any being much beyond its fellow-beings, but only just so much beyond them as to enable it to survive them in the struggle for existence." [1]

It is here maintained that there are many cases in the organic world where structure has been laid down as a preparation for function before the function could be brought into action, as truly as the shipwright, when he lays the keel on the land, intends the future ship to float on the water.

[1] From Wallace's essay on *The Limits of Natural Selection as applied to Man*, published among his "Contributions to the Theory of Natural Selection."

A Vital and Intelligent Agency shown in the Evolution of the Crustacea.—We have seen in the foregoing chapter, that there are some metamorphoses, especially those of the higher Crustacea, which it seems difficult if not impossible to account for as the result of either self-adaptation or natural selection, because the animal leads the same kind of freely swimming life through its successive stages of development, and undergoes no change of either habits or surroundings; and we concluded that this is a strong argument in favour of the tendency to organic progress being no mere resultant from "the action of the environment on the organism," as the doctrines which we are combating would make it to be, but a property of life as life. We have seen also that in the metamorphoses in question the successive stages of development probably represent successive stages in the descent of the existing mature forms; and that one stage, at least, of these metamorphoses—namely, the development of the long abdomen of the Zoea—appears to have been made, not for immediate but for future utility.[1] All this strongly tends to prove that the evolution of such forms as these has been due to an agency which is not inorganic but vital, and not blind but intelligent.

The same in the Evolution of Medusæ.—A similar and perhaps a stronger argument is to be drawn from the facts of Medusa development. We have seen that there is a transition, not only in the development of the individual, but through a series of nearly allied generic forms, from *Hydra*, in which the generative products are matured in mere enlargements of the wall of the animal's body, to such forms as *Syncoryne*, in which the generative organs become detached and independently living Medusæ;[2] —and supposing, what no believer in evolution can doubt, that such a series represents the actual process of evolution, by descent, of such a form as *Syncoryne*, we must infer that the agency which guided the evolution made preparation for the production of Medusa structure through generations—possibly

[1] See p. 294. [2] See p. 325.

countless generations—before the first Medusa was sufficiently matured to swim away.

I do not say that this is conclusive. Very few arguments of the kind can be so. It may be that the swimming-bell or umbrella[1] of the Medusa, during its development through ages before it left the stem, served as a respiratory organ, and, being thus directly useful, was matured partly through natural selection, and partly also through self-adaptation, to which principle growth through exercise belongs. This however appears improbable, because such lowly organisms as the Hydrozoa do not appear, in any ascertained case, to need or to possess distinct respiratory organs;—they breathe through the entire surface of the body.

The same shown in Ascidian Larvæ.—I go on to mention another remarkable case in which recent researches have brought to light what appears to be a structure in that incipient state wherein it is of no use to his possessor, and has been formed with the purpose of being useful, not at first, but after it has been perfected through countless generations. The great Vertebrate class of animals—that is to say, the class of animals which have a back-bone to support the body and to protect the chief nervous cord—has until lately appeared to be quite isolated from all other classes. The affinities of the members of that class had been traced from warm-blooded Vertebrates down to cold-blooded ones; from cold-blooded air-breathers like the Frog down to Fishes; from the higher fishes down to the Lamprey and the rest of the Cyclostome class, which have neither jaws nor fins; and from this down to the *Amphioxus*, which has no brain, no distinct heart, and no red blood, yet shows itself to be truly a Vertebrate, though the lowest of the Vertebrates, by the possession of a notochord, which is the structure that precedes the formation of the vertebral column in the developing embryo. In *Amphioxus* and the Cyclostomes the notochord remains through life; in most other Vertebrates

[1] See p. 327.

it is replaced, more or less completely, by a true vertical column.[1] But until lately the chain of affinities appeared to break off here; nothing was known which appeared to connect the Vertebrates with any Invertebrate class.

All Vertebrates present fundamentally the same mode of development. If the developing embryo of a Fish or a Frog, for instance, is watched under the microscope, a deep groove is seen to form itself on that side of the original structureless germ which ultimately becomes the animal's back, and at the bottom of this groove a band of cartilaginous substance, called the notochord, is laid down In all but the lowest Vertebrates, vertebræ are developed out of the tissue on each side of this, and form rings, enclosing the notochord and the spinal cord which is formed above it. In the higher Vertebrates the notochord is absorbed and disappears, but in many fishes more or less of it remains. The notochord is characteristic of all Vertebrates, and separates them from nearly all Invertebrates. But a discovery has been made within the last few years, which appears to supply the missing link between Vertebrates and Invertebrates, and to show from what lower forms vertebrate animals are most probably descended. The Ascidians are Molluscous animals of low organization; but it has been shown that some Ascidians, when first developing, present an almost perfect likeness to the first state of a vertebrate embryo, having the essential features of the dorsal groove and the band which is formed below it. In the case of the Vertebrates, the embryo undergoes a forward development, attaining to a higher organization; in the case of the Ascidians, the embryo undergoes a retrograde development, ending in a lower organization than that with which it commenced. But, if the theory of evolution be true, we may infer that an animal having the characters common to the Vertebrate and the Ascidian embryos was the common parent of both Vertebrates and Ascidians; and here we have the first beginning of vertebrate organization. But how will Darwinism account for this? As

[1] See the beginning of Chapter XIV.

we have seen, Darwinism requires that every variation shall be from the first generation advantageous to its possessor, because otherwise natural selection would not preserve it. Now, of what use can the dorsal groove and the incipient cartilaginous band below it be to these Ascidian larvæ? or of what use can they have been to the common ancestor of Ascidians and Vertebrates? The muscular system of an almost microscopic animal cannot need the support of a notochord, even if this is sufficiently consolidated to serve as a support; and the notochord cannot be serviceable for the protection of the nervous centres, because, when it first appears, it is situated below the rudiment of a nervous system, and does not attain, as does the developed vertebral column, to the form of a tube surrounding it. It seems to me that in these very curious facts we see two most important characters—the dorsal groove and the cartilaginous band below it—which no possible benefit to the animal itself will account for, and which were at first introduced by the guiding Intelligence that directs the work of evolution, not with a view to the benefit of the animals in which they first appeared, but with a view to the ultimate evolution of the Vertebrate class of animals from this lowly beginning. Here, to quote the words of Schiller, we "find in our search the Creator at His work."[1]

Development of Ascidian Larvæ described.—The following account of the development of these larvæ is condensed from Dr. Michael Foster's account of Kowalevsky's researches on the subject:[2]—

The fertilized ovum is first resolved into a double layer of cells, with a cavity *c* between, which afterwards becomes the "body-cavity" of the animal. The layer again doubles, forming the cavity *h*, which becomes the stomach. Fig. 1 shows this early stage of development, in which *h* is only a deep groove

1 "Beschleicht forschend den Schaffenden Geist."—*Der Spaziergang.*

2 "The kinship of Ascidians and Vertebrates," *Quarterly Journal of Microscopical Science*, January 1870. The diagrams in the text have been borrowed from the same paper.

not yet closed, and there is no suggestion of vertebrate structure. (In Figs. 1 and 2 the animal's body is shown as if in cross-section. Of course a section cannot be really obtained, but the transparency of embryonic organisms makes it needless.)

Fig 1.

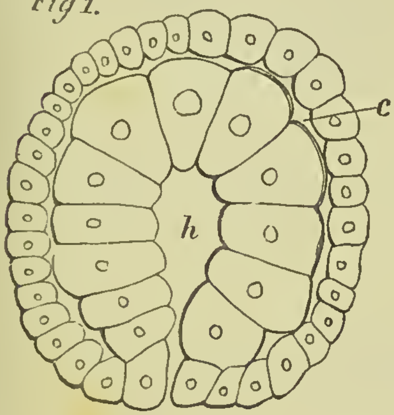
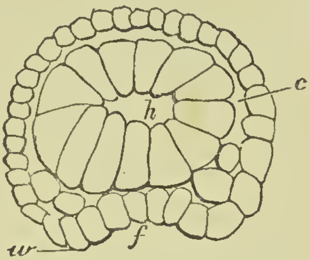


Fig. 2.



In Fig. 2 the groove *h* is closed and has become a tube. We also see the first suggestion of vertebrate structure, in the folds *w*, which rise up from the "body-wall" and form the groove *f*, at the bottom of which the "notochord," or cartilaginous band, which is believed to be homologous with a vertebral column, is afterwards laid down.

In Figs. 3 and 4 the parts of the body are shown as if in longitudinal section. Fig. 3 shows the last-mentioned groove at *n*: it is now much deepened; it still has an opening at *d*, but is doubled back on the left of *k* and *e*, the cells at *k* and *e* forming one of the walls of this new cavity. The cells of *g* surround the stomach, and have existed from the first; those at *s* have now first made their appearance, and constitute the rudiment of the notochord of the tail.

In the next stage of development, the body is bent, as shown in Fig. 4. The notochord is shown at *x*, farther developed than it was in Fig. 3, and the hinder part of the cavity *n* has been

Fig. 3.

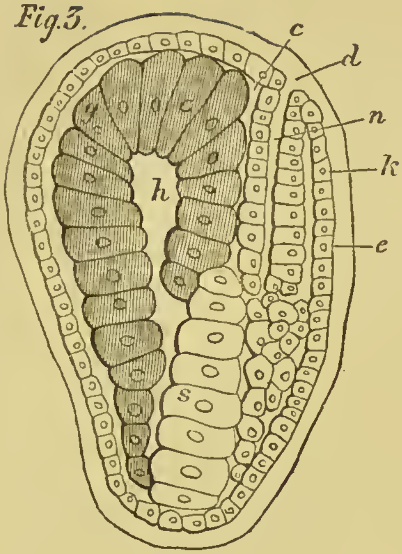
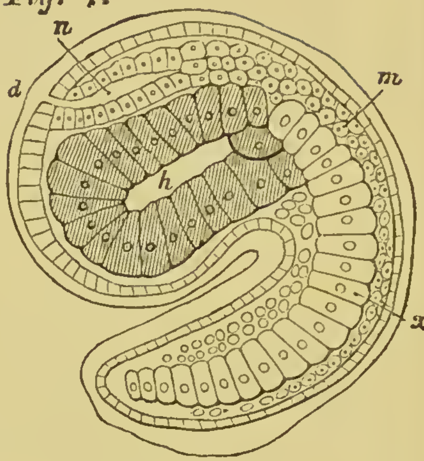
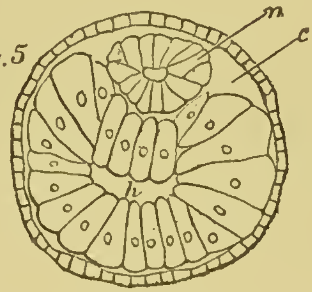


Fig. 4.



filled up with a growth of cells shown at *m*, probably consisting of nervous matter, and representing the spinal cord of the Vertebrate.

Fig. 5



In Fig. 5 we have again a cross-section, showing, as before, the stomach at *h*, the body-cavity at *c*, and the tube *n* formed by the notochord, which has now grown round the nervous matter shown at *m* in Fig. 4. Dr. Michael Foster says of this stage of its development—"Did the notochord but reach a little farther forward, we should have an exact diagram of the section of a Vertebrate body."

The animal undergoes farther development in what we may call the Vertebrate direction; but this is soon arrested, and the larva, like those Nauplius larvæ which turn into Barnacles and

Lerneæ,[1] undergoes a retrograde metamorphosis, and becomes a permanently sessile Ascidian, without a vestige of Vertebrate structure.

An Ascidian which does not undergo Metamorphosis.—It is no argument against the kinship between Ascidians and Vertebrates, that *Molgula tubulosa*, a sessile solitary Ascidian, passes through no larva state like that here described, but becomes attached as soon as it leaves the egg.[2] This is simply a case of development which has become direct through the loss of metamorphosis, like that of the frog *Hylodes Martinicensis,* which is developed directly and without passing through any tadpole state.[3]

Interpretation of these facts.—The probable inference from these facts is, that Vertebrates and Ascidians, utterly unlike as they are in their mature states, are both descended from a species that once existed, and may perhaps exist still, which in its mature state resembled these Ascidian larvæ. One descendant of this species underwent a progressive development, and from it, through some form resembling *Amphioxus*, the Vertebrates have been descended; another descendant underwent a retrograde development, and from it the Ascidians have been descended. Some of these preserve in their larval form a record of their ancestry; others—*Molgula tubulosa* at least—have lost it. But no principle of either self-adaptation or natural selection is capable of accounting for the development of the original form, by forming the dorsal groove (*f* in Fig. 2, *n* in Figs. 3 and 4), and then laying down below the groove the cartilaginous band (*x* in Fig. 4), before it could be of any use to its possessor. This can have been done only by an agency having foresight and purpose of developing it into a vertebral column, not

[1] See p. 288.

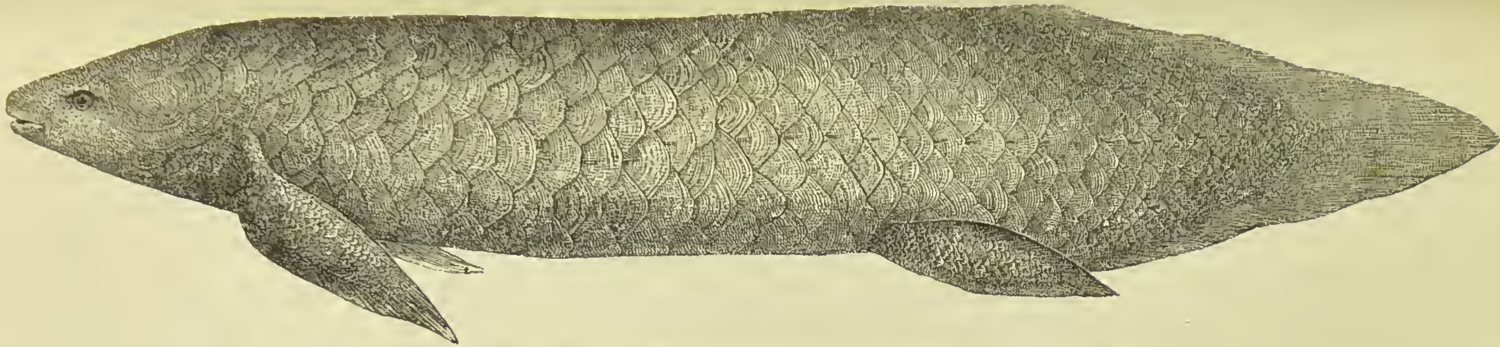
[2] See Dr. Rolleston's address to the British Association, 1870, as reported in *Nature*, vol. i. p. 445.

[3] See p. 281.

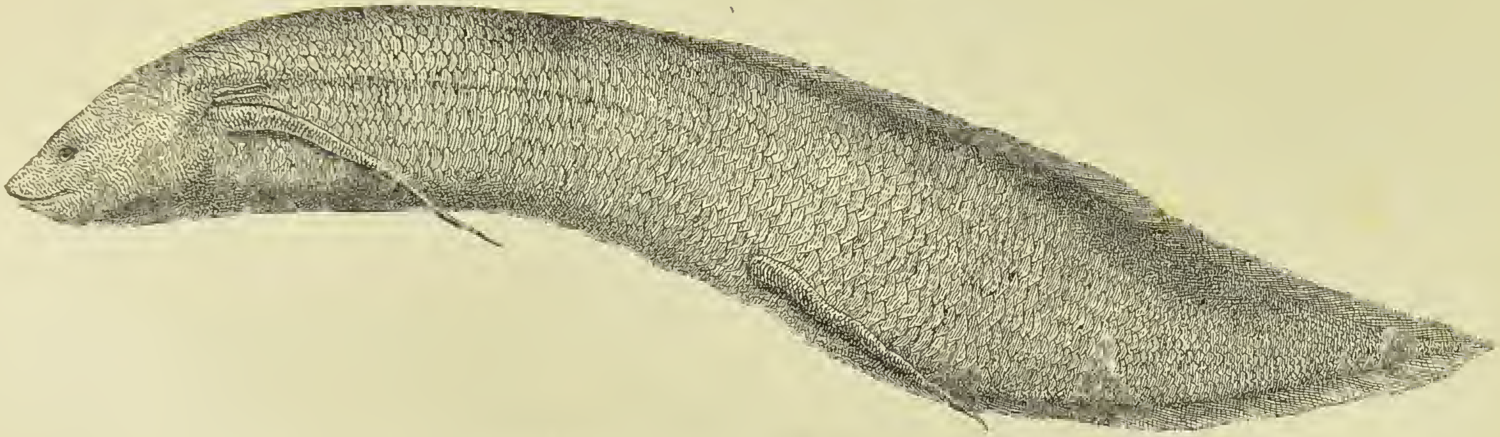
immediately but in the course of perhaps many millions of generations.

Transition from Fishes to Air-breathers.—We find similar indications of purpose and foresight in the transition from Fishes to air-breathing Vertebrates. It cannot be doubted that this transition has been through the Batrachian class, most of which pass their early life as tadpoles, breathing water and resembling fishes in their entire structure, and not acquiring either lungs or legs until they undergo metamorphosis. It is equally certain that the lungs of air-breathing Vertebrates are homologous with the swim-bladder of Fishes, and the legs of quadrupeds with the fins of Fishes; and if the doctrine of evolution is true, the lungs have been developed out of the swim-bladder, and the leg out of the fin, by descent with modification.

Transition from Swim-bladder to Lungs: Intelligent foresight.—The transition from the swim-bladder to the lung, great as is the change, presents no special difficulty. Among water-breathing animals generally, respiratory organs are remarkably inconstant as to their form and position;—in many Invertebrate classes, though not among Vertebrates, this inconstancy extends even to their existence;—every surface appears to be potentially a respiratory surface. Among the Ganoid order of fishes, from which the air-breathing Vertebrates appear to be descended, the swim-bladder is very generally cellular and spongy, thus presenting a transition to lung-structure; and this, which is in no way needed for the purpose of a swim-bladder, would appear to be a provision, made under the guidance of the Intelligent Power that guides evolution, for its future development, under favouring circumstances, into lungs. But supposing the swim-bladder, through whatever agency, to have acquired this spongy structure, the power of self-adaptation appears to be sufficient to account for its assuming the function of breathing air, when the animal is compelled to live in rivers or pools which are liable to be partly dried up during



Ceratodus, redueed from Dr. Günther's paper in the *Philosophical Transactions*, 1871.



Lepidosiren annectens. Drawn by Samue M'Cloy, from a specimen in the Museum of Queen's College, Belfast.

a portion of the year, and where consequently the supply of oxygen dissolved in the water is liable to fail. *Lepidosiren* and *Ceratodus*, which are the only known genera of fishes that breathe air, are inhabitants of such waters.[1] In this, as in all cases, the agency of self-adaptation will be aided by natural selection. It is difficult to imagine any case where the action of natural selection can be more certain and rapid than in this, because animals that cannot breathe with facility in the medium where they are compelled to live will soon perish.

Ceratodus and Lepidosiren.—The intermediate forms which must have once connected Batrachians with Fishes have not been found; but, as suggested in the foregoing paragraph, the still existing *Ceratodus* and *Lepidosiren* show how the transition to an air-breathing structure was probably made. It seems impossible, however, that the actual passage by descent from Fishes to Batrachians was made through either of those genera, or any form closely resembling them; for, though intermediate in their general character between the Ganoid Fishes and the Batrachians, they differ from both of these in the character of their scaly covering, and in having the anterior opening of the nostrils within the mouth.[2]

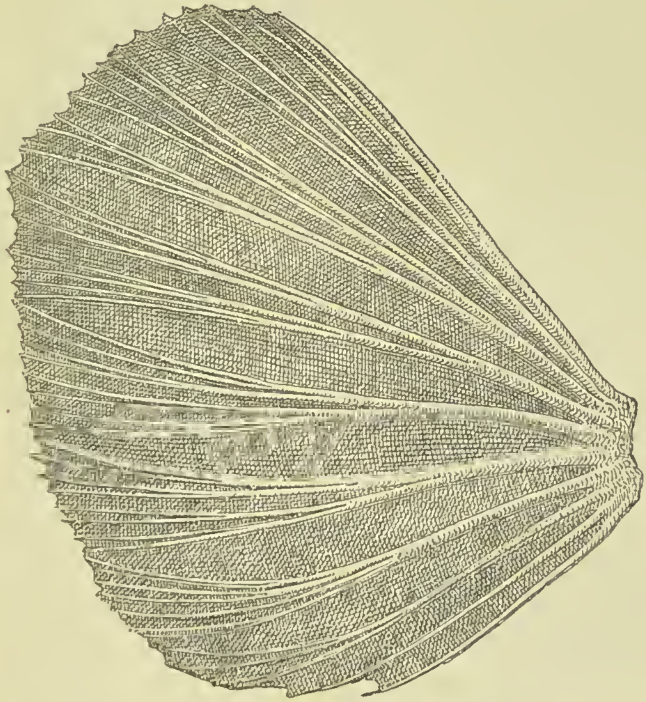
Transition from the Fin to the Leg.—These two genera also throw some light on the much more difficult question of the transition from the fin to the leg. How can a fin be changed into a leg by any Darwinian process? How can the transition be made without passing through an intermediate stage, in which the limb shall have lost its efficiency as a fin without becoming efficient as a leg? On Darwinism principles such a transitionary stage would be impossible, because an animal in such a state of inefficiency would have been destroyed, not preserved, by natural selection. Yet it appears, from what

[1] These two genera constitute the order Dipneusta, or Double-breathers. See p. 228.

[2] See pp. 228, 235.

evidence we have, that such a stage must have been passed through.

Fin-rays of Gurnard, Sturgeon, Ceratodus, and Lepidosiren.—The fins of most Fishes consist of rays supporting a membrane, and afford scarcely any suggestion of the possible formation of a leg. The fin of a Gurnard, here figured, is an instance of this kind.

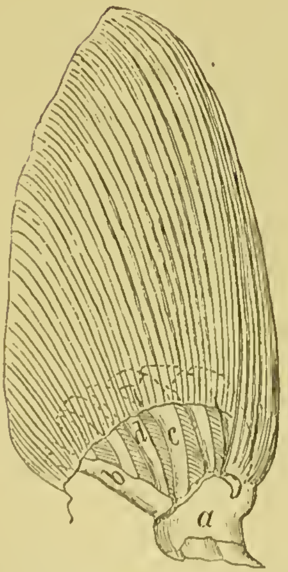


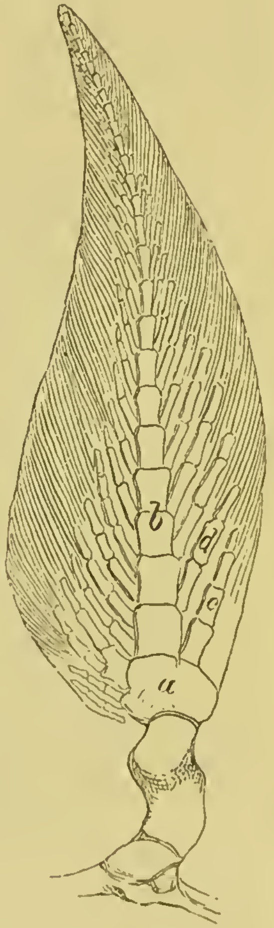
Pectoral fin of Gurnard (*Trigla*). Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast.

The fin of the Sturgeon is very differently constructed, and leads by a comparatively slight modification to that of the *Ceratodus* (see figures on next page);—the connexion of the parts, which is of the first importance in morphology, being the same in both.

It will be seen that both of these fins have a single bone *a* at the base, out of which arise two rays *b* and *c*, and *b* carries

secondary rays, one of which is marked at *d*. The chief difference between them is that in the Sturgeon the principal ray *b* has secondary rays, with their membrane, on only one side, while in the Ceratodus these are developed on both sides, so as



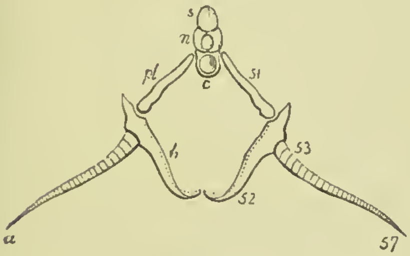


Pectoral fin of Sturgeon (*Acipenser*). Pectoral fin of *Ceratodus*.
From Dr. Günther's paper in the *Philosophical Transactions*, 1871.

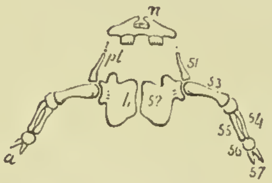
to give to the principal ray somewhat of the appearance of the midrib of a leaf.

All these three—the Gurnard, the Sturgeon, and the *Ceratodus*—have fins adapted for swimming. But the next term in the series is *Lepidosiren*, which in the anatomical sense indeed has

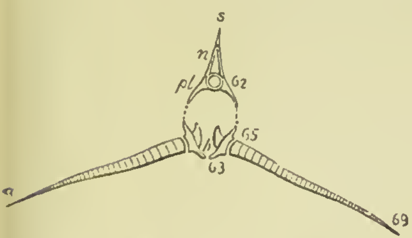
fins, but they are not swimming organs, being mere single rays without membranes. The fin-ray of *Lepidosiren* is in fact the fin of *Ceratodus* with the lateral rays and the membrane omitted, and only the median ray left, with its supporting bones. The external appearance of *Lepidosiren* is shown on p. 349; the connexion of its limbs with the rest of the skeleton is shown here.



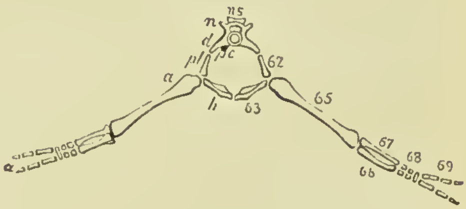
Scapular arch and limbs of Lepidosiren.



Scapular arch and limbs of Amphiuma.



Pelvic arch and limbs of Lepidosiren.



Pelvic arch and limbs of Amphiuma.

From Owen's *Anatomy of Vertebrates.*

Natural Selection cannot account for the loss of the fin-membrane in Lepidosiren.—It appears impossible to account for the transition from the fin of *Ceratodus* to the fin-ray of *Lepidosiren* by any means which Darwinism admits. Natural selection can produce, or rather can preserve, no changes except such as are beneficial immediately; and it seems impossible that the loss of the membranes of its fins can be beneficial to a fish. It seems to me that these facts can be interpreted only by supposing that an Intelligent Power has guided the evolution of

the fin of *Ceratodus* out of a fin resembling that of the Sturgeon, and the evolution of the fin-ray of *Lepidosiren* out of a fin resembling that of *Ceratodus*, with the purpose of ultimately evolving the leg of an animal fit for terrestrial life.

But we have seen that the existing Batrachians and other classes of air-breathing Vertebrates are not descended from *Lepidosiren* or any form nearly resembling it;[1] and this—if we can draw any inference from these facts at all—appears to show that there is a tendency in the Ganoid order of Fishes to produce, by a gradual process of evolution through indefinite generations, air-breathing forms suited to a terrestrial life. The existing Dipneusta (*Ceratodus* and *Lepidosiren*) are such forms, which, however, appear to have been arrested in their progress, and to have given origin to nothing higher than themselves. The existing air-breathing classes of Vertebrates are descended from some other series of forms, now lost or unknown, which evolved lungs out of a swim-bladder and legs out of fins by a process like that whereof we see the rudimentary beginnings in *Ceratodus* and *Lepidosiren*.

This hypothesis is rendered less improbable by what we know of the fact of "parallel variation," and especially by the development of Medusa structure in different orders of Hydrozoa. I advance it, however, as an unproved hypothesis; and I should scarcely think it worth putting forward if it stood alone; but it becomes credible when it is regarded as one out of many instances presenting more or less clear evidence of structure having been prepared in anticipation of function.

Transformation of fins into legs with toes. Amphiuma. Difficulty of natural selection here.—The next stage that is known to us in the evolution of legs out of fins is shown in the illustration on p. 353, where corresponding parts of the skeletons of *Lepidosiren* and of *Amphiuma* are represented side by side. *Amphiuma* is a newt or tailed Batrachian, and in its mature life has lost the gills with which it breathed water

[1] See pp. 288, 350.

as a tadpole. It will be seen that the limb of *Lepidosiren* ends in a single ray, and that of *Amphiuma* in two digits or toes;—the latter is the simplest form of the structure which has been variously developed into the feet of the highest quadrupeds, the wings of the Pterodactyle,[1] the Bird, and the Bat, and the hand of Man. How was this all-important transition effected, from a limb without digits to a limb with digits? In the present state of our knowledge, this question appears unanswerable. It seems inconceivable that the first small beginnings of digits should have originated in a mere spontaneous unguided variation; or that, if it did so originate, it should have been, from the very first, useful enough to be preserved by natural selection. We must however admit that too little is known of the subject for any reasoning about it to be at all conclusive.

I will remark, however, that if a series of intermediate forms, whether living or fossil, should be hereafter discovered, constituting the transition from such a fin as that of *Lepidosiren* to such a leg as that of *Amphiuma*, the mere existence of such a series will not prove that its development is due to natural selection or to any combination of unintelligent agencies. The existence of transitional forms may prove, and I think it does prove, the fact that there has been transition; but it does not necessarily prove anything as to the nature of the agency which has effected the transition. Thus, for instance, Prof. Mivart raises a difficulty as to the possibility of natural selection explaining the origin of the pedicellariæ of the *Echinus* or Sea-urchin (small organs somewhat like a hand of two fingers, which the animal uses in removing dirt);[2] and Darwin replies by pointing to the existence of a gradation, not through different species, but to be sometimes seen in the same individual, through organs of intermediate structure, between the animal's ordinary spines and the pedicellariæ. This fact is interesting;

[1] The Pterodactyles were an order of Reptiles organized for flight. Their bodies appear to have been naked, and their wings were rather bat-like than bird-like, though not very like either. See pp. 204, 205.

[2] See *Seaside Studies in Natural History*, by Alexander and Elizabeth Agassiz, reviewed in *Nature* of 11 Jan. 1872.

but most development has probably been gradual and through transitional forms, and it cannot be admitted that the fact of development being gradual necessarily proves anything as to the nature of the developing agency.

Greater difficulty in the evolution of the Bird's wing out of the Reptile's fore-leg.—The difficulty is even greater respecting the evolution of the Bird's wing out of the Reptile's fore-leg. It is probable that Birds are descended from Dinosaurians, an extinct order of Reptiles; the resemblance of the pelvis and the hinder-legs and feet of Dinosaurians to the same parts in Birds is so strong as to place the affinity beyond doubt; and there is reason to believe that some Dinosaurians were bipeds like Birds, walking on their hinder legs only. If this is so, or indeed if any theory of evolution is true, the Bird's wing must be derived, by descent with modification, from the Reptile's fore-leg; but it seems doubtful whether any organ having the function of a foot or of a hand could be changed by a gradual process into a wing, without passing through an intermediate state, in which it would be inefficient for either purpose;—and such a change would be immediately detrimental, and could not be effected by natural selection. The only possible suggestions as to the function of wings during their development, and before they were capable of being used as organs of flight, appear to be that they were used as balancers in running, like those of the Ostrich, or as swimming organs, like those of the Penguin.

The Ostrich and Apteryx.—This, however, is a subject on which we have no direct evidence. The Ostrich has a claw on its wing, which may possibly be a relic of the former state of the fore-limb as a foot or a hand; but it seems more probable that the Struthious order (to which the Ostrich belongs) have no special connexion with Reptiles, and do not represent a race of birds in the act of acquiring the power of flight, but on the contrary have lost the power. This is supported by the fact that the *Apteryx* of New Zealand, one of the same order, has no

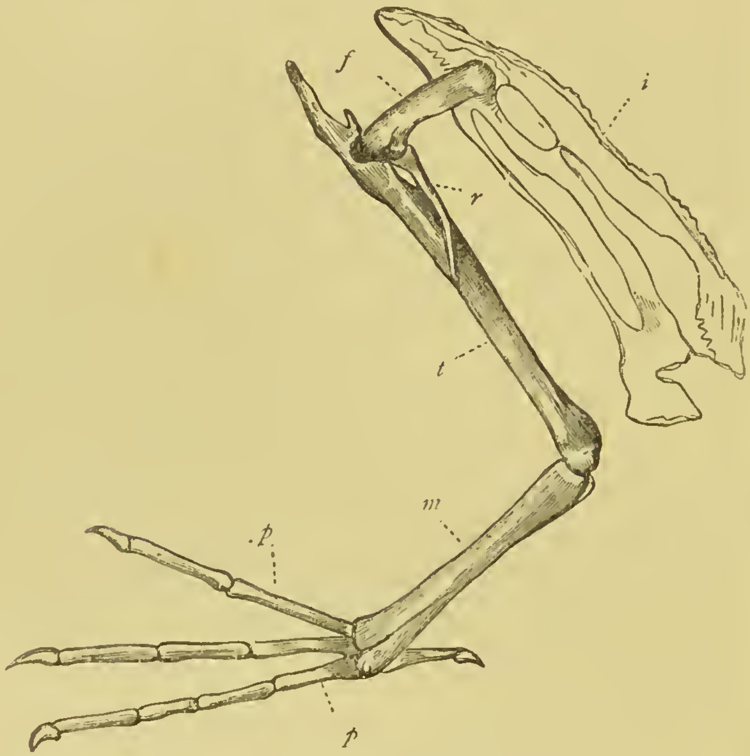
external wings whatever, though it has wing-bones ;—the rudiments of its wings are not in a state of functional activity, not even so much so as in the Ostrich; and when any organ is not functionally active, it must be inherited from ancestors in which it existed in a state of activity. We have already seen [1] that several birds, belonging to different orders, have lost the power of flight.

Origin of Birds. Archæopteryx.—It seems probable that the nearest known form in the class of Birds to that of Reptiles is not the Ostrich, or the *Apteryx,* or any resembling these, but the *Archæopteryx,* a fossil bird totally unlike these, having fully developed wings, and a long tail with a feather growing from each side of every joint. The long tail was probably injurious to the power of flight; and if the first birds had it, natural selection sufficiently accounts for its disappearance. For the same reason, a long tail cannot have been evolved among flying birds. These reasons, when considered alone, appear to make it certain that short-tailed birds must be descended from long-tailed ones, and not the reverse; and they are supported by the fact that fossil birds have been discovered which had the power of flight, and possessed teeth; for this latter character connects them with Reptiles.

Resemblance of Struthious birds to Dinosaurians.—But if this is true, the Struthious birds, which are also short-tailed, can have no special affinity with Dinosaurians, and any resemblance between them is due to a reversion of the Struthious birds towards the origin of the class. Such a reversion is not improbable in the case of birds that have lost the power of flight, but such a cause appears insufficient to account for the very strong resemblance which the skeletons of the Struthious birds present to those of some Dinosaurians, not only in the general form, but in the bones of the tail. We can scarcely see the two side by side without believing that there must be real

[1] See p. 130 *et seq.*

affinity. The difficulty is analogous to that respecting the origin of the Arthropoda.[1] There are strong reasons for believing that the Nauplius form is at the root of the entire Arthropod group, but this is difficult to reconcile with the worm-like characters of *Peripatus*, which nevertheless is a true Arthropod; and there are strong reasons for believing that some form



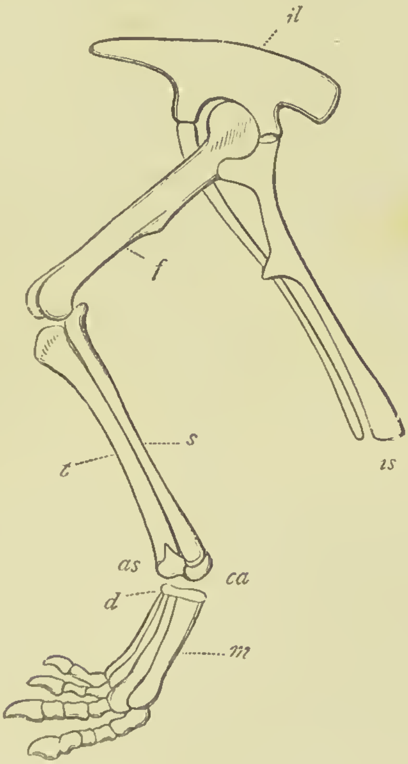
Hind-limb of the Loon (*Colymbus glacialis*) after Owen.
i Innominate-bone; *f* Thigh-bone or femur; *t* Tibia, with the proximal portion of the tarsus anchylosed to its lower end; *r* Fibula; *m* Tarso-metatarsus, consisting of the distal portion of the tarsus anchylosed with the metatarsus; *pp* Phalanges of the toes.

resembling *Archæopteryx* is at the root of the class of Birds, but this is difficult to reconcile with the resemblance of Struthious birds to Dinosaurians.

Pneumatic bones in a Dinosaurian. Preparation for Bird Structure.—In the Dinosaurian order there is moreover a very remarkable special preparation for Bird structure. The bones

[1] See p. 308.

of flying birds are mostly "pneumatic," that is to say, hollowed out for the sake of lightness combined with strength, and containing air-cavities. This is an adaptive character, and Pterodactyles had it also. It appears to be useless in any but a flying animal, and yet Prof. Cope says of a Dinosaurian named *Megadactylus probyzelus*, that "the bones are pneumatic, and



Leg of Dinosaur, after Huxley.
il Ilium ; *is* Ischium; *b* Femur ; *t* Tibia ; *s* Fibula ; *as* Astragalus ; *ca* Calcaneum ; *m* Metatarsus.

possessed of excessively thin walls."[1] No Dinosaurian had the power of flight; yet the pneumatic bones of *Megadactylus* were a preparation for a power of flight to be afterwards developed among Birds, as decidedly as Medusa structure was prepared for through unknown generations before the first Medusa was matured and swam away. It is important to observe that the

[1] See note on following page.

Struthious birds have not this character; and this is a strong reason for believing that the transition from Dinosaurians to Birds cannot be through that order. We must mention also that Struthious birds, like common birds, have no vestige of teeth.

So far as I am aware, the argument of this chapter is new; and if it were taken up by persons thoroughly versed in comparative anatomy and embryology, it seems probable that instances of structure in anticipation of function would be found everywhere in the organic world.

In the next chapter we shall have to consider the application of these principles to the evolution of the human race.

NOTE.

MEGADACTYLUS PROBYZELUS.

"Professor Cope gave the result of investigations on the structure of the extinct Saurian, the *Megadactylus probyzelus* of Hitchcock, from the red sandstones of the Connecticut valley in Massachusetts. He mentioned that in 1867 he had stated it as his belief that the so-called bird-tracks of the above formation were those of Dinosauria, and that in the following year that view had been confirmed by Prof. Huxley. . . . . The *Megadactylus* was the only species whose remains had been found in the beds and locality in question, in sufficient preservation for determination; and it was clearly one of those which had made the tracks. The fore-limbs were four-toed, the hind-limbs three-toed, and with a long metastarsus. The animal was a Dinosaur, and a true representative of the sub-order Symphypoda, which was typified by the *Compsognathus* of the Solenhofen beds. As in the latter, the astragalus and calcaneum were co-ossified with the tibia and fibula, and the carpal bones were much reduced. The bones were pneumatic, and possessed of excessively thin walls. The ischiatic bones were projected far backwards, were in contact for much of their length, forming a solid style which supported the animal when in a sitting position. Length about four feet."—From a communication to the American Philosophical Society on 7th January, 1870, as reported in *Nature* of 27th January, vol. i. p. 347.

CHAPTER XIX.

THE ORIGIN OF MAN.

In the foregoing chapter, we have seen reason to believe that there are many instances in the organic world of structures produced, not by the exercise of their functions, but in anticipation of functions to be exercised in future generations, and by forms not yet evolved. If this can be proved, the Darwinian theory is so far refuted;—such structures cannot have been produced by any unintelligent agency.

Wallace's argument—that natural selection is inadequate to the evolution of the brain of Man, from primitive Man having a brain developed beyond his actual attainments.—Of all structures which Darwinian principles cannot account for, the brain of Man is the most conclusive; perhaps, in the present state of knowledge, we ought to say the only perfectly conclusive instance. This has so impressed Mr. Wallace, who thought out the outlines of the theory of natural selection independently of Darwin, that, while agreeing with Darwin in referring all else in the organic world to the unintelligent and blind action of natural selection, he maintains that the evolution of Man alone gives proof of having been guided by an Intelligent Power. I have shown that I do not agree with this;—on the contrary, I maintain that the entire organic world, not to speak at present of the inorganic, is full of the traces of intelligent purpose and guidance; but those traces become constantly more clearly traceable as we ascend in the scale of being, and consequently

are clearest in Man, who is at once the crown and climax of the organic world, and in some sort a new and distinct creation.

Wallace's argument respecting the brain and mind of Man is an application of the same principle which in the present chapter I have endeavoured to prove applicable to many other cases;—namely, that neither natural selection nor any other unintelligent agency can account for an organism attaining to any perfection which is in anticipation of its actual requirements, and therefore not immediately useful. On this subject I will begin by quoting Mr. Wallace's own statement of the argument. After showing, what scarcely needs proof, that there is a connexion between mass of brain and power of mind, he says:[1]—

"The average cranial capacity of the lowest savages is probably not less than five-sixths of that of the average civilized races, while the brain of the anthropoid apes scarcely amounts to one-third of that of Man, in both cases taking the average; or the proportions may be more clearly represented by the following figures:—

Anthropoid Apes	10
Savages	26
Civilized Men	32

But do these figures at all approximately represent the relative intellect of these three groups? Is the savage really no further removed from the philosopher, and so much removed from the ape, as these figures would indicate?"

"Let us now compare the intellectual wants of the savage and the actual amount of intellect he exhibits, with those of the higher animals. Such races as the Andaman Islanders, the Australians, and the Tasmanians, the Digger Indians of North America, or the natives of Fuegia, pass their lives so as to

1 The following quotations are from Mr. Wallace's essay on *The Limits of Natural Selection as applied to Man*, published among his "Contributions to the Theory of Natural Selection." On the same subject, see "Natural Selection insufficient to the development of Man," by the Rev. George Buckle, *Popular Science Review*, 1871, p. 14. The last-named essay restates and expands Mr. Wallace's argument extremely well, but without adding much that is original.

require the exercise of few faculties not possessed in an equal degree by many animals. In the mode of capture of game or fish they by no means surpass the ingenuity or forethought of the jaguar, which drops saliva into the water and seizes fish as they come to eat it; or of wolves and jackals, which hunt in packs; or of the fox, which buries his surplus food till he requires it. The sentinels placed by antelopes and by monkeys, and the tree-shelter of some of the African anthropoid apes, may well be compared with the amount of care and forethought bestowed by many savages in similar circumstances. His possession of free and perfect hands, not required for locomotion, enables Man to form and use weapons and instruments which are beyond the physical powers of brutes; but, having done this, he certainly does not exhibit more mind in using them than do many of the lower animals.[1] . . . . And if this is true of existing savages, how much more true must it have been of the men whose sole weapons were rudely-chipped flints, and some of whom, we may fairly conclude, were lower than any existing race;" yet Mr. Wallace states in the same essay, that "the Engis skull, perhaps the oldest known, and which, according to Sir John Lubbock, 'there seems no doubt was really contemporary with the mammoth and the cave-bear,' is yet, according to Prof. Huxley, 'a fair average skull, which might have belonged to a philosopher, or might have contained the thoughtless brains of a savage.' Of the cave-men of Les Eyzies, who were undoubtedly contemporary with the reindeer in the south of France [and must consequently have lived during the Glacial period], Prof. Paul Broca says in a paper read before the Congress of Pre-historic Archæology in 1868:—'The great capacity of the brain, the development of the frontal region, the fine elliptical form of the anterior part of the profile of the skull, are incontestable characteristics of superiority, such as we are accustomed to meet with in civilized races;' yet the great breadth of the face, the enormous development of the ascending ramus of the lower jaw, the extent and roughness of the surfaces for the

[1] I quote this without being prepared to assent to it.

attaehment of the museles, espeeially of the masticators, and the extraordinary development of the ridge of the femur, indieate enormous museular power, and the habits of a savage and brutal raee."

In sueh eases, Mr. Wallaee coneludes that "the idea is suggested of *a surplusage of power;* of *an instrument beyond the wants of its possessor;*"[1] and we have seen that neither self-adaptation nor natural seleetion ean aeeount for this.

If it is said that the superiority of undeveloped or savage man to the brutes eonsists rather in possibilities of attainment than in anything aetually attained, this is true, but it eoneedes the point raised by Mr. Wallaee and myself.

Reply, that Man's first and most characteristic attainment is Language.—Another reply, however, is possible. It may be said that although the superiority of savage man to the brutes in skill and in the use of tools is not eomparatively great, yet the real superiority of Man eonsists in the faeulty of language; and that the mental power implied in this unique faeulty is represented by the very great exeess in the size of the human brain over that of the highest apes. Mr. Wallaee does not appear to have seen this, and yet it seems a suffieient answer to his argument, so long as we confine our attention to the contrast between savage man and the highest apes. If then the Darwinian theory is true of Man, the differenee between the brain of the highest ape and that of the lowest man is due to the exereise of the brain during the period while the power of language was in proeess of evolution, aided by the natural selection of the largest brains, in which, of eourse, this new power would be the most highly developed.

Language, when first evolved, is generally in advance of the intellectual wants of the race.—As a matter of faet, it is true that language is the first product of the mind of man;—language attains a high development while as yet the arts

[1] The italics are mine.

are undeveloped, political organization rudimentary, and science not dreamed of;—and afterwards, when science and the fine arts, especially mathematics and music, have grown into new faculties, and the useful arts have become new powers; and when political organization has made it possible for great empires to be orderly and coherent, and at the same time governed on principles of freedom; language undergoes no corresponding development—indeed, no development whatever; for the languages of the most highly civilized nations excel those of their barbarian ancestors, if at all, only in a greater abundance of words, and in more elaborate discrimination of their meanings; but have not attained to any greater abundance and power of grammatical forms. Language, in prehistoric times, appears to have attained to a development which must have been in advance of the intellectual necessities of the races speaking it, because the same languages still, without further development, suffice for the intellectual needs of their much more cultivated descendants. There are, no doubt, exceptions; Hebrew is poor in both words and grammatical forms. Arabic, however, is of the same stock with Hebrew; the Arabs of the pre-Mohammedan age must have been a very uncultured people, yet it is asserted that the Arabic of the Koran has a force and picturesqueness which are found to be untranslatable into the languages of modern Europe. The Sanscrit-speaking conquerors of India, also, were a rude people, yet Sanscrit is stated to be as perfect a language as that of ancient Athens. And a far inferior race to either of these, namely the Kaffir, has developed a language which, whatever its powers, has a regular system of inflections, and is said to be copious in an extraordinary degree.

The Evolution of Language cannot be accounted for on Darwinian principles.—This digression on the development of language is really, though perhaps not obviously, relevant to the subject of the development of the brain. On Darwinian principles, as Mr. Wallace urges, the brain of a race can grow only

if it is exercised; the brain of Man has grown enormously in the transition from the ape to Man; and what was there to exercise it in any degree corresponding to its growth? I reply, the formation of language. But this only removes the difficulty by a single step. Can the evolution of language itself be accounted for on Darwinian principles? I think not;—I think this is disproved by the fact above insisted on, that the languages evolved by primitive races are often, I believe we may say generally, far in advance of their intellectual needs.

But even in the case of a language, like Hebrew, of which this is not true, it is by no means evident that it could be evolved by anything like a Darwinian process. It is probable that the first germs of language consisted in the imitation of natural sounds (not in cries or interjections—they are the germ, not of speech, but of song, and ultimately of music). But is it possible for this germ to be developed into even the rudest and poorest of organised articulate languages by any Darwinian process;—that is to say, by any process wherein the only motive powers are the impulse of utility and the pressure of necessity, acting on the minds of successive generations? I think not. Probably all language, and certainly every language whereof the development is in advance of the intellectual wants of the race, needs for its evolution an intelligent mental impulse proceeding from within, and related to habit and natural selection in the same way as is the formative power which produces organic structures in anticipation of function.

Man's mental nature cannot be due to natural selection.—We have thus arrived, though by a different path, at the same conclusion with Mr. Wallace;—namely, that the evolution of Man's mental nature must have been effected by a Power transcending natural selection. And if this is true of the mind, it is equally true of the brain; for mind and brain, like any other function and its corresponding structure, act and re-act on each other's development.

Man's brain is a structure developed in anticipation of function.—But is the brain-structure of Man developed along with and parallel to its functions; or is its development in anticipation of its functions, like the cases dwelt on in the preceding chapter? Here again I agree with Mr. Wallace, though not altogether for his reasons. Not only among savages, but among the majority of individuals among the civilised races, when we compare the development of the brain, which is the organ of thought, with the intellectual development actually attained, "the idea is suggested" (to quote Mr. Wallace's words again) "of a surplusage of power; of an instrument beyond the wants of its possessor." In a civilised race, all the brains are approximately equal in magnitude (for the case of exceptionally small brains, such as are found in idiots, does not enter into the present argument); yet how great is the difference in intellectual development between the possessors of these brains! I do not speak of exceptionally endowed individuals;—the relation of genius to brain is an unsolved mystery, and likely to remain so. But consider, on the one side, the intellectual attainments of an utterly uneducated man, acquainted with only the commonest words of his own language, and unable to count except on his fingers; and on the other, those of a well-educated man, a master of two or three languages, a competent mathematician, and acquainted with the principles and the more important results of science;—yet the difference between the intellectual attainment of the two—attainment not only in the sense of knowledge, but of real, though acquired, power—is not represented by any corresponding difference between their brains. When thus we find that the brain of every civilized man, as a rule, has the magnitude and the organization which suffice for the high culture which nevertheless is actually attained by only a small minority, the conclusion appears certain that a Power, acting in some other way than by the blind and unintelligent forces of habit, self-adaptation, and natural selection, has perfected Man's brain through long ages of ignorance and barbarism, for the needs of knowledge and civilization.

Testimony of Moralists to the same effect.—The most competent of those who have studied human character as moralists, endeavouring to understand it not by science but by sympathy, will, I believe, be found to unite in bearing witness to the same truth, of the existence of a great reserve of unused and only half-discovered faculty in most men. And if some are blinded to this by the contempt for men which is often produced by much familiarity with them, this very feeling of contempt is the result of a dim perception of the same truth. No one despises dogs or horses;—what awakens, though it does not justify, contempt, is the perception in man of an unrealized ideal—a falling short of what he was intended to be. To the same cause is to be ascribed the widely-spread, though utterly untrue, belief of a state of higher virtue and happiness than the present having been once enjoyed by Man. The myth-creating imagination has represented the falling short of an ideal state as a fall from an actual one.

It is probably true that the adaptation of living beings to the circumstances of their lives is never perfect, but only a close approximation; but the approximation is so close that for most purposes its deviation from perfection may be disregarded. How different is the mental nature of Man! It is perhaps no exaggeration to say that every sane human being is born with faculties which are never perfectly developed; and that those whose early promise is the highest, fall the farthest short of fulfilling it. It is a saying, I believe, of Goethe's, that if all children were to develop their natures on every side alike, all would grow up into men of genius. But even if there is no other reason, this is made impossible by the fact that youth is too short for the development of the character on all sides alike; and when youth is past, the power is lost of beginning development in a new direction. Auguste Comte wished that he could have two or three hundred years for study; but if, like Tithonus, he had forgotten to ask for continued youth, he would probably have found the greater part of such a life utterly barren, from the difficulty of turning the mind to new subjects.

Mr. Wallace on Man's hairless back.—Besides his unique mental nature, there are several peculiarities of Man's bodily structure which Mr. Wallace[1] mentions as being impossible for natural selection to produce. "In Man the hairy covering of the body has almost totally disappeared; and, what is very remarkable, it has disappeared more completely from the back than from any other part of the body. Bearded and beardless races alike have the back smooth, and even when a considerable quantity of hair appears on the limbs and breast, the back, and especially the spinal region, is absolutely free, *thus completely reversing the characteristics of all other mammalia.*" This character cannot have been produced by ordinary natural selection, because it would have been injurious to any animal whatever in the wild state; and there are few if any races, however savage, which do not wear clothing of some kind as a substitute for the hairy covering that they have lost. Darwin suggests that the hairy covering may have been lost by a species, now extinct, of our ape-like ancestors, through sexual selection:—that is to say, through the preference given to hairless mates, whereby those with least hair were most frequently able to leave offspring. No evidence of this is offered, and I cannot think it in the slightest degree probable. It has been suggested that the absence of hair might be beneficial to an animal living in a warm climate, by making it less liable to the attacks of parasites; but this will not account for the nakedness being most complete on the back.

But though the absence of hair on Man's back must have been almost purely injurious while he was emerging out of the merely animal state, yet its subsequent effect, as Mr. Wallace remarks, must have been very great, and probably on the whole highly beneficial, by making shelter and clothing necessary, and thereby stimulating industry and invention.

Man's faculty of Music.—Mr. Wallace further says:—"The same remark will apply to another peculiarly human character;

[1] The following quotations are from the essay already quoted. The italics are mine.

—the wonderful power, range, flexibility, and sweetness of the musical sounds produced by the human larynx, especially in the female sex. The habits of savages give no indication of how this faculty could have been developed by natural selection, because it is never required or used by them. The singing of savages is a more or less monotonous howling, and the females seldom sing at all. Savages certainly never choose their wives for fine voices ; . . . . sexual selection could not therefore have developed this wonderful power, which only comes into play among civilised people. *It seems as if the organ had been prepared in anticipation of the future progress of Man*, since it contains latent capacities which are useless to him in his earlier condition. The delicate correlations of structure that give it such marvellous powers could not therefore have been acquired by means of natural selection."

The same may be said of the perceptive and inventive powers which make the art and science of music possible.

Conclusion ;—What is most characteristic in Man is not due to natural selection.—We conclude, that what is most characteristic in Man's bodily and mental nature cannot be the result of natural selection. And we must here recall the fact mentioned in a previous chapter,[1] that the usual relations of the sexes are in one most remarkable way reversed in Man ;—the sex in which the passions are the weakest being in Man alone, of all known species, that in which the highest beauty is developed.

[1] See p. 276.

CHAPTER XX.

THE RATE OF VARIATION.

Geological time is too short for Darwin's theory.—The chief purpose of the present chapter is to show that geological time is too short for the origin of species by that slow modification, dependent on general diffused variability, which Darwin maintains to be the chief process in organic development; and, consequently, that modification must have been a much more rapid process than Darwin allows.

Flora and Fauna of the Galapagos.—Before entering on the general question we will consider a very remarkable special case. The Galapagos are a group of volcanic islands in the Pacific; like all volcanic islands they are geologically very modern, and are consequently a locality where we could not expect to find characteristic forms; because, on the Darwinian theory, there cannot have been time for any such to be evolved. Yet the Galapagos, which "are so recent that some of these islands are barely covered with the most scanty vegetation," have that vegetation "itself peculiar to these islands. Some parts of their surface are entirely bare, and a great many of the craters and lava streams are so fresh that the atmospheric agents have not yet made an impression on them." "They belong to our time, geologically speaking. Whence, then, do their inhabitants come from, animals as well as plants?"[1]

[1] L. Agassiz in *Nature*, 19th September, 1872.

Their peculiar Lizard, the Amblyrhynchus.—One of their animal inhabitants is one of the most peculiar forms to be found anywhere, namely the *Amblyrhynchus,* a lizard allied to the Iguana, but aquatic, and the only aquatic lizard known to exist. It feeds on seaweed, but is of course an air-breather like the rest of its class, and sometimes leaves the water and rests on the shore. This singular species is found nowhere except in the Galapagos, and consequently has most probably been evolved there; but, on Darwinian principles, how can so peculiar and aberrant a form have been evolved during the geologically very short time that has passed since those islands first rose above the ocean? This case has been pointed out as an objection to Darwin's theory by the younger Agassiz.[1]

But this, which appears to be true of the Galapagos—that their duration has been too short to admit of the species inhabiting them being evolved by a Darwinian process—is also true of our entire planet.

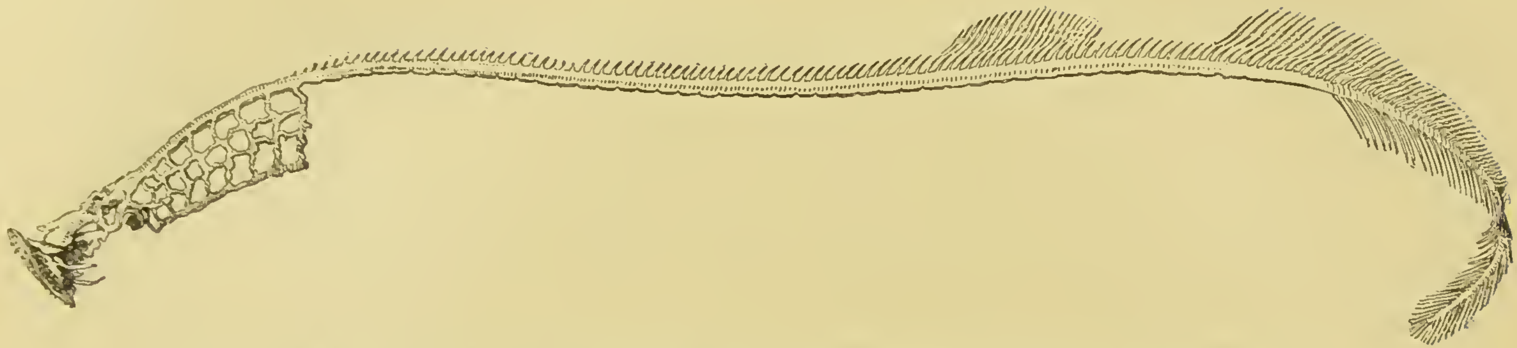
Age of the Earth stated by Sir W. Thomson at about 100,000,000 *years.*—Sir William Thomson has calculated, by applying the mathematical laws of the cooling of heated masses to the facts ascertained respecting the rate of increase of the earth's temperature in descending from the surface, that the time which has elapsed since the earth's surface was sufficiently cooled to be the abode of living beings is probably not much more than one hundred, and almost certainly not more than about four hundred, millions of years.[2] Such a period so transcends imagination that it may at first seem amply sufficient for any process whatever. But let us see what sort of periods the Darwinian theory requires.

Periods required by the Darwinian theory.—Prof. Mivart thinks,[3] and Darwin probably would not dispute this, that we cannot believe a distinct species to have been formed and

[1] *Nature*, 29th August, 1872. [2] See note at end of Chapter.
[3] *Genesis of Species*, p. 157.

established by such a process as natural selection in less time than about a thousand years. If, then, it takes this period to form a species, it ought to take something like ten times as long to form a genus, a hundred times as long to form a family, at housand times as long to form an order, and so on; the periods, as Prof. Mivart remarks, increasing not in arithmetical but in geometrical progression, as we go on to wider and wider groups, separated by greater and greater differences. Suppose, for instance, that it took a thousand years to develop the lion out of the original stock of the cat genus, it should then take ten thousand years to develop the cats out of the original stock of the sub-order to which cats and dogs alike belong, and one hundred thousand years to develop this out of the original stock of the Carnivorous order, which was probably more like a badger or a weasel than a cat or a dog. To develop this out of the original stock of the placental Mammalia would take a million of years, and ten millions to develop this out of the original stock of all the Mammalia, which was no doubt implacental, and probably more like the *Ornithorhyncus* and *Echidna* than any other known animal, though not very like them. To develop the first mammal out of a reptile must probably have required ten times this, or a hundred millions of years; to develop the first true reptile out of a newt, a hundred millions of years more; and it must have taken at least as long for a fish with jaws and fins to be developed out of a form resembling the Lamprey and other Cyclostomes, which have neither.[1] It is perhaps not too much to guess a thousand million years as the time required to develop a Cyclostome like the Lamprey, which has a distinct heart and red blood, out of a form like the *Amphioxus*, which, though a vertebrate, has white blood and no distinct heart; at least as long to develop this out

[1] It is not meant that the Vertebrates with jaws are descended from an ancestor which had a suctorial mouth like a Lamprey, as shown in the illustration. It is more probable that all existing Vertebrates are descended from an ancestor which had neither jaws like the higher Vertebrates nor the cartilaginous ring which surrounds the mouth of the Lamprey.



Skeleton of Lamprey (*Petromyzon*). Drawn by Samuel M'Cloy, from a specimen in the Museum of Queen's College, Belfast. The framework behind the head is a cartilaginous support of the gills, and is not represented in the higher Vertebrates.

Skeleton of *Ceratodus*, reduced from Dr. Günther's paper in the *Philosophical Transactions*, 1871.

of an animal resembling an Ascidian larva;[1] and as much more to develop this out of a Protozoön consisting of a minute gelatinous mass having life and motion, but no trace of structure. We thus conclude that the time needed for the evolution of the highest forms of life out of the lowest would probably require, on the Darwinian theory, more than three thousand millions of years, while the entire duration of geological time cannot have been much more than one-eighth of this.

Of course this estimate is not offered as making the slightest approach to accuracy. It is only an attempt to show the ever-multiplying length of the periods needed for greater and greater evolutionary changes, and to suggest how it may perhaps be possible to estimate, not the magnitudes themselves, but the order of the magnitudes. But our estimate errs on the side of making the periods too short; and this in several ways. In the first place, we have greatly understated the number of gradations of groups subordinate to groups in the classification; and, in the second place, we have made no allowance for what there is good reason to believe to be the fact, namely that variation of sufficient magnitude to give origin to new species is not going on always, but only takes place at intervals. Darwin strongly insists on this. It is probable that the last-mentioned fact would warrant us in multiplying the period by at least some such number as ten, if not by some such number as a hundred.

Organic progress is slowest in the lowest groups.—In another way, also, the length of the periods required by Darwin's theory has been underrated. We have supposed that the time needed for any given change is proportional to the amount of change, and that the proportion is the same throughout the entire scale of organic being. But this is not the case. The time—a thousand years—which we have assumed for the formation of a species, is derived from our knowledge of the higher animals,

[1] See p. 342 *et seq.*

especially those in the domestic state. Respecting the rate at which the lower organisms undergo modification, we have no direct knowledge whatever; we only know, from geological evidence, that the lower we descend in the scale the less rapid is organic progress. Prof. Marsh says:—[1]

Prof. Marsh on this subject.—"This brings us to an important point in palæontology, to which my attention was drawn several years since—namely the comparative value of different groups of fossils in marking geological time. In examining the subject with some care, I found that for this purpose plants, as their nature indicates, are most unsatisfactory witnesses; that Invertebrate animals are much better; and that Vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, moreover, and, in fact, all forms of animal life, are of value in this respect, mainly according to the perfection of their organisation or zoological rank. Fishes, for example, are but slightly affected by changes that would destroy Reptiles or Birds, and the higher mammals succumb under influences that the lower forms pass through in safety."

Conclusion as to periods required.—If we multiply the time needed for Darwinian evolution by ten for each of the two last-named factors, that is to say, for the time during which change is not going on, and for the slower rate of change among the lower and more numerous organic grades, we get three hundred thousand millions of years as the required period; and this would be again multiplied several times if we assumed anything like the true number of groups subordinate to groups.

The question of the periods demanded by Darwin's theory may be approached in another and a somewhat different manner.

[1] In a lecture "On the Introduction and Succession of Vertebrate Life in America;" as reported in *Nature*, 27th September, 1877.

Origin of the Bat's wing.—It must have appeared to every one who has considered the subject at all, that the great *crux* of Darwinism is the origin of complex organs like the eye and the ear. But before we speak of this, let us consider a case which is specially favourable to Darwinism: I mean the origin of the Bat's wing. This involves no very complex adjustments; it may have been effected for the most part by single variations, assisted by self-adaptation. A process of change by means of single variations is made specially easy by the fact that when any part has begun to vary it tends to continue variable, especially in the direction of continuing and increasing the first variation. Darwin says on this subject:—[1]

Darwin on continued variation.—"Continued divergence depends on the same parts continuing to vary in the same direction. The tendency to general variability can be inherited, even from one parent. It is in itself probable that when an organ has varied in any manner it will continue to vary in the same manner. If a gardener observes one or two additional petals in a flower, he feels confident that in a few generations he will be able to raise a double flower, crowded with petals. Some of the seedlings from the weeping Moccas oak were so prostrate that they only crawled along the ground."

To return to the subject of the origin of the Bat.

Darwin on the Flying Squirrel, the Flying Lemur, and the Bat.—The Bat's wing, when in the nascent state, probably resembled the parachute of the Flying Squirrels. I quote the following from Darwin:[2] "Look at the family of Squirrels: here we have the finest gradation from animals with their tails only slightly flattened, and from others, as Sir J. Richardson has remarked, with the posterior part of their bodies rather wide and the skin on their flanks rather full, to the so-called Flying Squirrels; and Flying Squirrels have their limbs, and even the

[1] *Variation under Domestication*, vol. ii. p. 241.
[2] *Origin of Species*, p. 208.

base of the tail, united by a broad expanse of skin, which serves as a parachute, and allows them to glide through the air to an astonishing distance from tree to tree. . . . Let the climate and vegetation change, let other competing rodents or new beasts of prey immigrate, or old ones become modified, and all analogy would lead us to believe that some at least of the Squirrels would decrease in numbers or become exterminated, unless they also became modified and improved in structure in a corresponding manner. Therefore I can see no difficulty, more especially under changing conditions of life, in the continued preservation of individuals having fuller and fuller flank-membranes, each modification being useful, and each being propagated, until, by the accumulated effects of this process of natural selection, a perfect so-called Flying Squirrel was formed. Now, look at the *Galeopithecus*, or Flying Lemur, which formerly was falsely reckoned among Bats. It has an extremely wide flank-membrane, stretching from the corners of the jaw to the tail, and including the limbs and the elongated fingers: the flank-membrane is also furnished with an extensor muscle. Although no graduated links of structure fitted for gliding through the air now connect the *Galeopithecus* with the other Lemuridæ, yet I see no difficulty in supposing that such links formerly existed, and that each had been formed by the same steps as in the case of the less perfectly gliding Squirrels; and that each grade of structure was useful to its possessor. Nor can I see any insuperable difficulty in further believing it possible that the membrane-connected fingers and fore-arm of the *Galeopithecus* might be greatly lengthened by natural selection: and this, as far as the organs of flight are concerned, would convert it into a Bat. In Bats which have the wing-membrane extended from the top of the shoulder to the tail, including the hind-legs, we perhaps see traces of an apparatus originally constructed for gliding through the air rather than for flight."

It may be necessary to state that no one supposes the Bats or the Flying Lemur to be descended from a Squirrel. The unlikeness of the other parts of the organism excludes this.

But the Bat's wing, during its evolution, has successively resembled the membranes of the Flying Squirrel and of the Flying Lemur. It was thus a gliding animal at first, and the membranes were useful to it from the time they began to exist. There is no difficulty in believing that the Bat would transform itself from a gliding into a flying animal, by acquiring the power of flapping its wings as soon as this became useful; if mere animal intelligence were not sufficient to originate such an instinct, it might begin in some spontaneous variation, much less strange than that in which the characteristic habit of the Tumbler Pigeon began. Other changes would follow, chiefly, perhaps, from self-adaptation, aided, as always, by natural selection;—especially the necessary changes in the muscles, and the acquisition of the keel on the sternum, as in Birds:—which last is an adaptive character, being found alike in the Bird, the Bat, and the Pterodactyle.

Natural selection inadequate to this.—In the first edition of this work I expressed the opinion that natural selection alone was sufficient to account for the origin of the Bat's wing. I maintained this on the ground that single variations, if preserved, are sufficient to give origin to an organ which is itself almost quite simple, and has few close correlations with other organs. I have since then, however, come to think differently; partly in consequence of the imperceptibly small advantage that can be secured to a Squirrel by a slightly flattened tail, or by the skin on the flanks being rather full; partly in consequence of the very small extra chance of survival that will be ensured to an individual, even by a decidedly favourable variation.[1] It seems more probable that these are what I have elsewhere called structures in anticipation of function,[2] indicating a purpose of gradual improvement into the fully developed membrane.

Inutility of the first small variation.—This difficulty of the uselessness of the first variation does not apply to the improve-

[1] See p. 185, *et seq.*

[2] See Chapter XVIII.

ment of already existing organs.. The muscles of a race may no doubt be strengthened, or its senses made more acute, by natural selection among small variations. But this depends on these variations being useful from the first. Darwin admits, and insists, that not only the new organ or other improvement must be advantageous when perfected, but that every successive step in the improvement must be separately advantageous to the generation in which it is effected, if natural selection is to be efficacious at all; and the case just mentioned, of a Flying Squirrel's membrane, appears to be but one of a vast number of cases in which the first slight variation would be of no sensible utility.[1]

Improvements lost by interbreeding with unimproved individuals.—This difficulty is greatly increased in the case of all the higher animals, by the fact that every one which is born has two parents, while there is an almost overwhelming probability that the favourable variation is found in only one; and as the offspring, when the difference between the parents is but slight, are, on the average, of intermediate character, the favourable variation will be transmitted to the offspring in only half its original force; and to their offspring again, with only half of this, or one-fourth of its original force; and so on, constantly weakening, except in so far as it is counteracted by the effect of fresh variations. This will not prevent the slow and gradual improvement of the race by the Darwinian process, when the variations are of such a nature that the smallest variation in the direction of improvement will be sensibly useful, as in the case of stronger muscles or acuter senses; but in wild races this cause must always greatly retard improvement, and must prevent it altogether when the greatest possible utility of any individual variation is insensibly small.[2]

[1] This was first made evident to me by a conversation with Mr. Alfred Bennett soon after the publication of the first edition of this work. See his paper on "Natural Selection from a Mathematical Point of View," read before the British Association in 1870, and printed in *Nature* of 10th November of the same year.

[2] See Edward Fry's letter in *Nature* of 27th April, 1871.

The discovery of intermediate forms does not explain transition.—In the foregoing extract respecting the Flying Squirrel, and perhaps throughout his entire system, Darwin seems too much inclined to think that the difficulty of accounting for the origin of any character or any structure is explained, if the stages through which it has probably been developed can be pointed out. This is not always satisfactory;—before the explanation can be called complete we must have the cause assigned for the successive modifications;—and I have endeavoured to show that in the case now under consideration natural selection is not a sufficient cause.

Self-adaptation does not act in the case of flying membranes.—It is to be observed also, that self-adaptation can have no part in forming the membrane of the Flying Squirrel or Bat. Self-adaptation can, no doubt, increase the size and strength of wing-muscles which are used, but it can have no tendency to increase the width of gliding or flying membranes.

Protective structures.—There are many other structures to which the same difficulties apply, both as to self-adaptation and as to the inutility of the first small beginnings. This is true of some, though not all, protective structures. The skin hardens and thickens in any place that is exposed to rough usage; this is a case of self-adaptation, and it may become hereditary, as in the instance of the knuckles of the Gorilla.[1] But such cannot be the origin of the shell that protects the Bird's egg. Without this protection no egg could be hatched, and the whole tribe of Birds would perish. But the contact of comparatively hard and rough substances, which make the shell necessary, cannot have the slightest tendency to produce the shell; for the shell is formed, and from the necessity of the case must be formed and completed, before any such contact can take place.[2] This cannot be explained as a structure which has been first formed for one purpose and afterwards turned to another; for

[1] Spencer's *Principles of Biology*, vol. ii. p. 295. [2] Ibid, vol. i. p. 440.

it appears impossible that egg-shells can ever have been formed under different circumstances from the present. The same is true of the bony or cartilaginous skulls that protect the cephalic ganglia in the Cephalopoda (Cuttlefish and Nautilus), and in the Vertebrata, and of the hard woody shells that protect the seed in nuts. The fact that there is something to protect cannot be a physical cause of the production of a protective structure.

Origin of complex organs.—But, however we may answer this question in the case of simple structures, how much greater is the difficulty in the case of highly complex organs, such as the eye and the ear? Here, also, self-adaptation can do but little;—it can no doubt increase the sensitiveness of the retina; but neither the action of light on the eye, nor any action of the eye itself, can have any tendency whatever to produce the deposit of black pigment that absorbs the stray rays, nor to shape the transparent humours into lenses, nor to form the iris.

The difficulty as to natural selection is almost as great;—it consists in this, that a number of parts must vary together; if they do not fulfil this condition no improvement can be effected; and if variation is unguided, the probability of this is almost infinitely small. If we suppose that any single variation occurs on the average once in m times, the probability of that variation occurring in any individual will be

$$\frac{1}{m};$$

and suppose that x variations must be combined in order to make an improvement, then the probability of the necessary variations all occurring together will be

$$\frac{1}{m^x}.$$

Now suppose, what I think is a moderate supposition, that the value of m is 1,000, and the value of x is 10: then

$$\frac{1}{m^x} = \frac{1}{1{,}000^{10}} = \frac{1}{10^{30}}.$$

A number about ten thousand times as great as the number of

waves of light that have fallen on the earth since historical time began.

So small a probability, or so great an improbabilty, as this, cannot be practically distinguished from impossibility. If the chances of obtaining favourable working variations—real improvements—are so small as these, the hope of organic progress by means of natural selection is no greater than that of obtaining a poem or a mathematical demonstration by throwing letters at random on a table.[1]

Darwin replies to this, that "if the eye were to be abruptly and greatly modified, no doubt many parts would have to be simultaneously altered, in order that the organ should remain serviceable. But is this the case with smaller changes?" And he goes on with the following interesting and suggestive remarks:—

Darwin on the Adaptation of the Eye.—"There are persons who can see distinctly only in a dull light, and this condition depends, I believe, on the abnormal sensitiveness of the retina, and is known to be inherited. If a bird, for instance, received some great advantage from seeing well in the twilight, all the individuals with the most sensitive retina would succeed best, and be the most likely to survive:—and why should not all those which happened to have the eye itself a little larger, or the pupil capable of greater dilatation, be likewise preserved, whether or not these modifications were strictly simultaneous? These individuals would subsequently intercross, and blend their respective advantages. By such slight successive changes, the eye of a diurnal bird would be brought into the condition of that of an owl, which has often been advanced as an excellent instance of adaptation. Short sight, which is often inherited, permits a person to see distinctly a minute object at so near a distance, that it would be indistinct to ordinary eyes; and here

[1] An attempt to produce literary compositions by a method similar in principle to this was being made in Laputa at the time of Gulliver's visit to that country, but it appears not to have been continued long enough to yield any result.

we have a capacity which might be serviceable under certain conditions, abruptly gained. The Fuegians on board the *Beagle* could certainly see distant objects more distinctly than our sailors, for all their long practice. I do not know whether this depends on nervous sensitiveness or on the power of adjustment in the focus; but this capacity for distant vision might, it is probable, be slightly augmented by successive modifications of either kind.

"Amphibious animals require and possess, as Dr. Plateau has shown,[1] eyes constructed on the following plan:—'The cornea is always flat, or at least much flattened in front of the crystalline, and over a space equal to the diameter of that lens, while the lateral portions may be much curved.' The crystalline is very nearly a sphere, and the humours have nearly the same density as water. As a terrestrial animal became more and more aquatic in its habits, very slight changes, first in the curvature of the cornea or crystalline, and then in the density of the humours, or conversely, might successively occur, and would be advantageous to the animal under water, without serious detriment to its power of vision in the air."[2]

The Greyhound.—There is much force in this argument, and I dismissed it too summarily in the first edition of the present work. We have seen in a previous chapter that selection can combine characters,[3] so that different advantageous characters may be combined in a single race, though inherited from different ancestors, which were separately selected on account of those characters; and a perfect co-ordination of structure may be obtained in this way. Darwin points to the case of the greyhound, all the parts of which are together "adapted for extreme fleetness, and the running down of weak prey;"[4] and the Greyhound is an artificial variety, formed by selection under domestication.

[1] *Annals of Natural History*, 1866, p. 469.
[2] *Variation under Domestication*, vol. ii. pp. 222, 223.
[3] See p. 189.
[4] *Variation under Domestication*, vol. ii. p. 221.

Difficulty about the Combination of Variations.—I do not, however, think that these instances prove, or go near to proving, that natural selection among small unguided variations can form such an organ as the eye. On that theory, the evolution and perfectionment of a complex organ are the result of a great number of small improvements, arising in distinct variations and combined by cross-breeding. This is not so hopelessly contrary to the law of probability, as if it were necessary for all the variations to occur together; but it must be a very much slower process than the perfectionment of a simple organ like the Bat's wing; and even if there are no difficulties, either in the nature of the case, or from the shortness of geological time, in believing that a simple organ might be produced by a Darwinian process, it may still be contended that the same is not true of a highly complex organ.

Difficulty about the needed Variation arising.—There is moreover this further flaw in Darwin's reasoning on the subject. He appears to take for granted that one variation, or the variation of one part of a structure, is as likely to occur as another; and that therefore the exact variation which is needed is certain to occur, if only time enough is allowed for the process of the evolution. It is obvious that this is all-important; for such an organ as the eye would be useless if it were left imperfect in a single important part; if, for instance, one of the lenses were considerably out of focus. Now, the assumption which Darwin thus tacitly makes appears inconsistent with fact. We do not find that one variation is as likely as another; on the contrary, we find that different species are variable in different degrees; that one part of an organism is more variable than another; and that among variable parts there is a tendency to variations of a particular kind, and an equally remarkable steadfastness of character in other respects. I will again mention a striking fact as to the constancy of a character which cannot be of first-rate importance to its possessors. The so-called Cyclostome Fishes, such as the Lamprey, which have no jaws nor fins, have

also only one nostril, but all other Vertebrates have two nostrils.[1] It is impossible to give any reason for the absence of variation in this functionally unimportant character; but it is important as showing that indefinite and equal variability in all directions alike is not a law of nature.

Eyes of Insects, Vertebrates, and Cephalopods.—The difficulty of believing that the eye can have been produced by natural selection, is greatly increased by the fact that it has been formed not on one only, but on at least three distinct lines of descent. Well developed eyes are found in the higher orders of Arthropoda, Mollusca, and Vertebrata. We need not here discuss the question whether these three groups had a common ancestor;—if they had, they must have diverged from the original stock long before the evolution of eyes. The eyes of Vertebrates and of Arthropods (*e.g.* Insects) are as unlike each other as we can conceive two highly elaborate organs of sight to be. The question has been debated whether those of the Cephalopoda (Cuttlefish and Nautilus), which are the highest of the Mollusca, bear any true resemblance to the eyes of the Vertebrata; and the conclusion appears to be, that though the mode of development is quite different, the eyes when perfected are wonderfully alike.

Increase of the difficulty from the Co-existence of many Organs in the organism.—The time needed for evolution, and with it, the difficulty in accepting Darwin's theory as a complete account of the origin of species, is again indefinitely increased by the fact that every one of the higher organisms is not a single complex organ, but a congeries of complex organs. If the time needed for the evolution of such an organ as the membrane of the Flying Squirrel is a thousand years (and probably Darwin would think this much underrated), the time needed for an improvement of equal magnitude in a complex organ which needs ten co-operating variations, in order to make any

[1] See p. 227.

considerable improvement, cannot be taken at less than the same multiplied by the square of ten, making one hundred thousand years; and for the time needed to effect similar improvements in ten complex organs at once, we must again multiply this by a hundred, making ten millions of years. If it is argued that these latter changes need not be approximately simultaneous, I reply that if so, the period needed will not be shortened but lengthened.

Ten millions of years, as we have seen, constitute at least a sensibly large fraction of geological time, and more than can be afforded for a change of any less magnitude than that which separates class from class;—consequently much more than can be afforded for such a change as that which only separates order from order.

The foregoing estimate, however, greatly underrates the periods needed;—and this in two ways. When we consider the immense complexity of the higher organisms, it will be evident that the number of modifications, in different parts of the body, needed for any important transition, such as that from one order to another, is much underrated at ten; and, moreover, if ten co-operating variations have to be effected, the time needed will probably be much more than a hundred times as great as if only one were needed. I cannot make any suggestion as to what function of the number of variations the time is likely to be. I have mentioned the square, not as a probable estimate, but as the lowest conceivable, though I admit that the algebraic formula on p. 382 is on the other hand an overstatement.

We thus conclude that the time needed for the perfectionment of a complex organ is indefinitely greater than that needed for a simple one; and that the time needed for the perfectionment of several co-operating organs in the organism is indefinitely greater than that needed for one organ.

Variations which must be absolutely Simultaneous to be Useful. The two Nervous connexions of the Iris.—In the present Chapter, we have reasoned as if the occurrence of the variation

which is needed for the improvement of any particular organ were only a question of greater or less probability. It is probable however that this is too large a concession to Darwinism, and that there are many combinations which it is impossible for unguided variation to produce at all;—practically impossible, I mean, in the same sense that it would be impossible to form a sentence having a meaning by throwing letters at random on a table. I refer to cases where two or more improvements will be useless, and consequently will not be preserved by natural selection, unless they are absolutely simultaneous. We can point to at least one instance of this—namely, the two nervous connexions of the iris of the eye. One of its nerves has its root in the brain, and contracts under the stimulus of light; the other has its root in the sympathetic ganglia, and opens the pupil again when the intensity of the light is diminished. It is obviously impossible that the efficiency of either of these two nerves could be increased separately; they will not be improved at all unless they are improved together; and, except in so far as self-adaptation will act, such improvement, on Darwin's principles, can be effected only by accidental favourable variations occurring in both at once. But such coincidences are so improbable that they may be left out of account as if they were impossible. I cannot mention any other instance which is equally conclusive, but I should think that any accomplished anatomist might enumerate many such in the structure of all the higher animals.

NOTE.

THE AGE OF THE EARTH, DEDUCED FROM ITS RATE OF COOLING.

Professor Everett's Statement of Sir William Thomson's Results.—In a paper on Underground Temperature, reprinted from the *Proceedings of the Belfast Natural History and Philosophical Society*, 1874, Professor Everett has given a concise account of Sir William Thomson's results on this subject. After showing that the earth's internal heat has no sensible effect on the temperature of its surface, he proceeds :—

"A good approximation to the law of cooling of the superficial parts of

the earth will be obtained by supposing the whole earth originally raised to a uniform high temperature, then the surface brought instantaneously to another uniform temperature, and permanently maintained at this second temperature. It is also allowable to treat the earth as an infinite solid with a plane surface ; for it can be shown that even after the lapse of a thousand million years, the original temperature will exist almost unchanged at depths exceeding five or six hundred miles.

"Sir William Thomson has worked out the problem on these suppositions, and finds that the thermometric gradient [that is to say the rate of increase of temperature in descending, or the reciprocal of the number of feet per degree of increase] at depth x after the lapse of a time t from the cooling of the surface, is represented by the formula

$$\frac{V}{\sqrt{\pi \kappa t}} e^{-\frac{x^2}{4 \kappa t}}$$

Where V denotes half the difference of the two temperatures [which are identical with the temperatures at great depths in the earth and at its surface], κ the conductivity [of the substances whereof the earth is composed], divided by the thermal capacity of unit volume [of the same,] and π the ratio of the circumference of a circle to its diameter.

"Putting $x = o$ in the above formula, we find for the thermometric gradient near the surface, the expression

$$\frac{V}{\sqrt{\pi \kappa t}}$$

Giving κ the value deduced from the Edinburgh observations [on the temperatures at various depths in the earth at different seasons in the year,] and supposing the initial difference 2 V, to be the difference between the melting point of rock and the present atmospheric temperature, Sir William Thomson finds that when t is one hundred million years, the value of tho second expression is $\frac{1}{50}$ (one-fiftieth) of a degree Fahr. per foot, which we know from observation to be approximately the present thermometric gradient. A gradient of $\frac{1}{60}$ (one-sixtieth) of a degree per foot will require the valuo of t to be 144 million years.

* * * * * *

"The limit of 100 or 150 million years which the above calculations assign to the earth's age as a habitable globe, will be brought still closer if we choose to reject the postulate that the earth was originally at the temperature of fusion. For instance, if we suppose the initial temperature to have been the arithmetical mean between the present surface temperature and the temperature of fusion, we thereby assign to V in the second formula only half the value above estimated, and must therefore divide t by 4 in order to keep the value of the expression unaltered."

In Sir William Thomson's words, the further back the time of heating the hotter it must have been. The best for those who draw most largely on time is that which puts it farthest back, and that is the theory that the heating was enough to melt the whole.

That is to say, if the initial temperature be taken at the highest that theory allows, which is that of melted rock, the time during which the earth has been cooling from that temperature has been about 100 million years; and if the initial temperature was only half of this, the time has been only a fourth, or 25 million years. It needs no proof that the higher was the original temperature of the earth, the longer must have been the time required for it to cool down to the moderate temperatures which we find at accessible depth.

Allowance for possible less Conductivity at High Temperatures.—Sir William Thomson, as we have seen, while calculating about 100 millions of years as the possible age of the earth, estimates about 400 millions as the greatest possible age.[1] This is not from anything doubtful in either the soundness of the mathematical method or the trustworthiness of the observations on underground temperatures and the specific conductivity of rock; but because of our ignorance of the value of that conductivity at very high temperatures.

Professor Tait on Geological Time.—Professor Tait reduces the possible age of the earth still further. He says:—"We can say at once to geologists, that granting this premiss, that physical laws have remained as they are now (and that we know of all the physical laws which have been operating during that time), we cannot give more scope for their speculations than about ten, or say at most fifteen, millions of years." He does not however state by what reasoning he has arrived at this conclusion.

[1] See p. 372.

CHAPTER XXI.

CONCLUSION ON THE ORIGIN OF SPECIES.

In the preceding Chapter, we have seen that Darwin's theory of the origin of species demands practically infinite time, and that geological time is not long enough for its demands.

Darwin's Theory requires the Number of the Individuals of a Species to be practically Infinite.—Darwinism also requires a practically infinite number of individuals,[1] in order to give the necessary chance of favourable variations not only arising but being preserved, in number sufficient to establish a new race. Darwin, from the first, insisted on the importance of a large number of individuals, in order to multiply the chances of favourable variation; he has laid emphasis on the ascertained fact that it is impossible to improve a domestic race by selection alone without cross-breeding, unless the race is numerous, so that there may be ample materials for selection; and he maintains, with great probability, that the power which plants introduced from the Northern hemisphere are now manifesting to overpower and supersede the native vegetation of the Southern (as in La Plata and New Zealand) is altogether due to the greater extent of land in the Northern hemisphere, which has produced more individuals and a greater number of local and

[1] The expression *practically infinite*, though in common use, may appear inaccurate or misleading; but our real meaning when we speak of a practically infinite number is one whereof the reciprocal is indistinguishable from zero, and practically without magnitude.

other varieties, and consequently has given rise to more competition and greater improvement. And the necessity, for the purpose of Darwin's theory, of a large number of individuals, is greatly increased by the admission in the later editions of his *Origin of Species*, that the chances are not in favour of, but against, the preservation of favourable variations under a state of nature, if they arise singly; and that a considerable number must present the variation in order to give it any approximate certainty of being preserved.[1] Now, is the number of the individuals of a species usually so great as the theory requires? In the case of rare or local species, it appears certain that this cannot be so.

This condition cannot be fulfilled in the case of local Mimetic Species.—The reply may be, that the process of modification is not always going on, and that only abundant and widely spreading species give origin to varieties which eventually become new species. This appears to be Darwin's opinion, and it is probably true in the majority of cases, but there is at least one very remarkable class of cases to which it will not apply. I mean those of mimicry, where the mimicking form is at once confined to a limited district, and rare within the district;[2] as in the instance previously mentioned, where if we "travel a hundred miles, more or less, from a district where one *Leptalis* imitates one *Ithomia*, a distinct mocker and mocked, equally close in their resemblance, will be found."[3] In such a case as this, it seems impossible that the number of the individuals of a species can be sufficiently great, not only to yield individuals presenting the required variations, but to yield them in number sufficient to eliminate the effect of "fortuitous destruction;"[4] and the circumstances of their existence forbid

[1] See p. 187 of the present work.

[2] See Mr. Alfred Bennett's paper on "Natural Selection from a Mathematical Point of View," read before the British Association in 1870, referred to on p. 380.

[3] See p. 250.

[4] See pp. 186, 188.

the supposition that they were ever much more numerous than at present.[1]

Darwin's Theory requires Indefinite Variability, and this is contrary to Fact.—We have next to show that the facts of organic variation contradict another postulate which is necessary if Darwin's theory is to work—namely, the postulate of general, diffused, and indefinite variability.

The Pigeon.—No species has been so wonderfully modified under domestication as the Pigeon. Sir John Sebright used to say, though probably with some boastful exaggeration, that by cross-breeding and selection he could produce any required feather in three years, but it would take six years to produce head and beak. But in the domestic varieties of the Pigeon, the possibilities of variation appear, in some directions at least, to have a limit which is already reached. Mr. Wallace remarks: "The Fantail has not only more tail-feathers than any of the three hundred and forty existing species of Pigeons, but more than any of the eight thousand known species of Birds. There is, of course, some limit to the number of feathers of which a tail useful for flight can consist, and in the Fantail we have probably reached that limit."[2] But the Fantail is a domestic variety, which has no more need for the power of flight than has the barn-door fowl; and, as Professor Mivart remarks in quoting this passage,[3] if "utility for flight" were the limit, there would be no reason why a Fantail should not be bred with two more tail-feathers than any Pigeon has yet developed. Mivart further says:[4]—"Let a Pigeon be bred with a bill like a Toucan's, or with the two middle tail-feathers lengthened like those of the King Bird of Paradise, or even let individuals be produced which exhibit any marked tendency of the kind, and the claim to indefinite variability shall be at once conceded."

[1] See p. 254 for the probable origin of protective mimicry.
[2] *Contributions to the Theory of Natural Selection*, p. 293.
[3] *Genesis of Species*, p. 132.
[4] *Ibid.* p. 133.

The more important Transitions have been Sudden.—We have seen that the characters of domestic varieties as distinct as natural species, have in several established instances originated by sudden variations;[1] and in considering the facts of classification, we have seen that those greater variations which distinguish orders rather than species appear to be due not to any diffused and indefinite variability, but to sudden and definite acts of variation;—so definite, indeed, that many of them have occurred several times over.[2] This appears to be especially true of those characters which are of morphological and classificatory significance without being adaptive, such as the formation of the flower and fruit among Plants,[3] and the character of the scales and the position of the fins among Fishes.[4] As characters like these do not affect the external life of the organism or its chances of survival, their preservation cannot be due to natural selection, but, if it can be accounted for at all, is most probably to be referred to Delbœuf's law.[5]

In such cases the tendency to Reversion is overleaped.—When a species or race has been formed by the Darwinian process of selection, whether natural or artificial, among small variations, there is a tendency to revert to the original character of the race; though it appears probable that this will wear out with lapse of time. But when a species comes into existence by a single sudden variation, the tendency to reversion appears to be as it were overleaped, and the new race is as distinctly established in a single generation, and as free from any tendency to revert to the characters of the parent stock, as could be effected by the Darwinian process in an indefinite number of generations. Thus, as we have seen, the peach has at several times given origin to the nectarine at a single variation; and the nectarine has not any greater tendency to revert to the peach, than the peach to go on producing the nectarine.[6] Only

[1] See Chapter XI. (The Facts of Variation).
[2] See Chapters XIII. and XIV.
[3] See p. 224.
[4] See p. 236.
[5] See p. 241.
[6] See p. 168.

by this power to overleap, by sudden and considerable change, the tendency to reversion, can we account for the remarkable constancy, throughout entire orders, of characters like those mentioned in the preceding paragraph, which are of little or no importance to the life of the organism.[1] The tendency to reversion, however, is not totally got rid of, but may appear in ways that we cannot explain.[2]

The power to produce Hybrids also disappears.—The power to produce hybrids appears also to be in a great degree lost in the formation of a new race by sudden variation; for though the new variety and the parent stock are fertile together at first, and perhaps for an indefinite number of generations, the progeny have the characters of either one parent or the other separately, and not in combination.[3]

Indefinite Variability: Change produced by Isolation.—But though we maintain that the greater changes which produce classes and orders, have been in most cases due to sudden, definite, and considerable variations, we do not deny that slight indefinite variability appears to be a law of life. It is for this reason that isolation is of itself sufficient to produce change. That is to say, if a colony of any species were to be isolated from its kind, we can scarcely doubt that after some generations it would come to constitute a distinct variety. Such cases have occurred under domestication, and they must have been of constant occurrence in nature whenever colonies have been isolated by the formation of ocean or other barriers.

Instance among Sheep.—Youatt gives an excellent illustration of the effects of a course of selection, which may be considered as unconsciously followed, in so far that the breeders could never have expected, or even have wished, to produce the result which ensued—namely the production of two distinct strains. The two flocks of Leicester sheep kept by Mr. Buckley

[1] See p. 221. [2] See p. 183 for instances. [3] See p. 153.

and Mr. Burgess, as Mr. Youatt remarks, "have been purely bred from the orignal stock of Mr. Bakewell for upwards of fifty years. There is not a suspicion existing in the mind of any one at all acquainted with the subject, that the owner of either of them has deviated in any one instance from the pure blood of Mr. Bakewell's flock, and yet the difference between the sheep possessed by these two gentlemen is so great, that they have the appearance of being quite different varieties." [1] In a case like this, it is perhaps impossible to say how much of the change is due, as Darwin seems to think, to an unconscious difference in the principles followed in selection; how much to slight differences of locality—for no two localities can be altogether alike in climate and everything else; and how much to the innate tendency to variation.

Variability and Modifiability: Dogs.—Variability, or tendency to spontaneous variation, is not identical with modifiability, or capacity for acquiring functionally produced changes. There is, however, some reason for believing that these two properties are, to a great extent, found together, at least among the highest animals. The wonderful modifiability of the mental faculties of the Dog, which has enabled him to acquire new instincts under domestication, is probably in some way connected with the variability of his form, which has given origin to such different races as the Greyhound and the Terrier.

Difficulty about the Loss of the Hinder Limbs of the Cetacea.—I will here mention what appears to be a case of special difficulty—I mean the loss of the hinder limbs of the Cetacea or Whale tribe. These, on any theory of evolution, must be descended from quadrupeds; and when their fore-legs were changed, by whatever process of modification, into paddles, it would seem to be at once a smaller and a more beneficial change for the hind-legs to be modified in the same way than to disappear. There would be nothing anomalous in such a position

[1] Darwin's *Origin of Species*, p. 26.

for swimming organs; the Ichthyosaurus and Plesiosaurus had four paddles placed like the legs of a quadruped, and those Fishes which present what must be regarded as the most typical form of the class have the same arrangement of fins.[1]

Independent tendencies to Variation and Progress.—In view of the facts which we have noted in treating of Parallel Variation, and of the Fixation of Characters,[2] we can scarcely doubt that there is a greater innate tendency to vary than can be accounted for as the effect of change of external conditions; and the facts noted in the Chapters on Metamorphosis and on Structure in anticipation of Function [3] appear to prove that there is an innate tendency to organic progress, not to be resolved into the effect of natural selection. Moreover, we have seen that though the higher organisms are superior to the lower in power and efficiency, the lower ones have the advantages of being both more enduring and more prolific; and that consequently there are no conclusive grounds for believing in any general tendency of the higher organisms to prevail over the lower as the result of mere natural selection.[4]

Formative principle in low organisms resembling that of Crystals: Acanthometræ.—Among crystals there are definite and very peculiar formative laws, which cannot depend on anything like organic functions, because crystals have no such functions; and it ought not to surprise us if there are similar formative or morphological laws among organisms, which, like those of crystallization, cannot be referred to any relation of form or structure to function. Especially is this true of the lowest organisms, many of which show great beauty of form, of a kind that appears to be altogether due to symmetry of growth; such as the beautiful star-like rayed forms of the Acanthometræ, which are low animal organisms not very remote from the Foraminifera. They appear to consist of nothing but structureless sarcode, with

[1] See the illustrations on pp. 209 and 239 as contrasted with that on p. 238.
[2] Chapters XIII. and XIV. [3] Chapters XVII. and XVIII. [4] See p. 191.

a skeleton of silicious spicules. They are allied to the Thalassicollidæ; but while the Thalassicollidæ are comparatively indefinite in form, the Acanthometræ are remarkably definite, being symmetrically radiated like flowers. Yet this definiteness of form does not appear to be accompanied by any corresponding differentiation of function between different parts—or, in other words, by any physiological division of labour; and, so far as we can see, the beautiful regularity and symmetry of their radiated forms are altogether due to unknown laws of symmetry of growth, just like the equally beautiful and somewhat similar forms of the compound six-rayed, star-shaped crystals of snow.

Diatomaceæ.—I quote the following instance of the same kind of beauty resulting from regularity, from the Duke of Argyll's *Reign of Law.*[1] The Diatomaceæ, a group of the lowest Algæ, "have shells of pure silex, and these, each after its own kind, are all covered with the most elaborate ornament—striated, or fluted, or punctured, or dotted, in patterns which are mere patterns, but patterns of perfect, and sometimes of most complex beauty. . . . In the same drop of moisture there may be some dozen or twenty forms, each with its own distinctive pattern, yet all as constant as they are distinctive, yet having all the same habits, and without any perceptible difference of function."

Correlation of Structure in the higher organisms.—The foregoing instances are from among the lowest organic classes. But even in the highest, the structure appears in a certain degree to be determined by laws of correlation which are more analogous to those of crystalline formation than to any adaptation of structure to function. In speaking of the facts of variation, we have seen that homologous parts tend to vary alike;[2] and this is only an extension into small variations of the principle of homology between different parts of the organism. Thus, the fore and the hind legs in quadrupeds, and the hands

[1] People's Edition, p. 190. [2] See p. 172.

and the feet in Man, are evidently homologous, not only in their relation to the rest of the skeleton, but in the number and position of the bones. The resemblance is carried much further than the law of adaptation to purpose will account for. That law will not account for the fact that there are both five fingers and five toes. If the hand needs five fingers for its uses, and no more, the foot might have done perfectly well with fewer than five toes.

Similar facts in Crystallization.—It ought not to surprise us to find this principle of correlation pervading organic morphology. The wonder would be rather if we did not find laws of the kind. But what I wish to lay emphasis on is, that correlation in organic morphology is totally distinct from adaptation to function, and is much more nearly akin to the correlations of crystalline morphology. No doubt a correlation of form may serve a purpose. For instance, the correlation, amounting to exact similarity of form, between the external organs on both sides of the body among nearly all the Vertebrata and Articulata, is much more convenient than any unsymmetrical arrangement could be. But this will not apply to the correlation between the hands and the feet. The fact that the toes are the same in number as the fingers, is a case of pure correlation, and has nothing to do with adaptation. These facts can only be compared to the laws of crystalline morphology, that edges and angles which are similarly related to similar axes are themselves similar; and that when the normal form of the crystalline species is modified, homologous edges and angles are modified alike. This is true not only of modifications that arise spontaneously in the process of crystallization, but of such modifications as are accidentally or artificially produced by breaking off an edge or an angle. Lavalle has found that if a crystal of alum is placed in pure water until its edges and angles are dissolved away, and then put into a solution of alum, the edges and angles will form again. There is nothing wonderful in this; but he has also found that if one of the angles is cut off such

a crystal, and the crystal put into the solution lying on the cut-off angle, so as to prevent that angle from growing again, a corresponding truncation will form, as the crystal grows, on the opposite angle.[1]

Similarities of Structure between parts of the organism which are not homologous.—It is also very generally the case that different parts of the same organism, even when not homologous, are formed in much the same way. In other words, both the tissues, and the manner in which the tissues are combined into organs, are alike in the different parts of the same organism. Thus, bone is peculiar to the Vertebrata, and is found both in the spine and in the limbs; and the bones of both the spine and the limbs are covered by the muscles. In the Articulata, which in many respects form a contrast and a kind of inverted resemblance to the Vertebrata, the body is divided into segments, and the limbs also are jointed; and in both the body and the limbs, the hard parts cover the muscles, instead of being covered by them: so that the type of their construction is opposite to that of similar parts in the Vertebrata. In the Mollusca there is no skeleton at all, with the single exception of the cartilaginous skull and the horny beak of the Cuttle-fish tribe (for the shell cannot be regarded as a skeleton); the body is not segmented, and there are no jointed limbs, only soft tentacles. Yet this is not connected with any inferiority of organization, for the organs of vegetative life among the Mollusca are very highly organized; and the Cephalopoda (Cuttle-fish and Nautilus), which are the highest Molluscan class, stand as high in the animal scale as any of the Invertebrata. It belongs to the same class of facts that the stem and the arms of Crinoids are jointed in a nearly similar way.

Organizing Intelligence.—It is obvious however that such formative principles as these can advance us no way whatever in accounting for what we have called the *crux* of Darwinism, namely

[1] Dana's *Mineralogy*, vol. i. p. 138.

the origin of complex adaptations like those of the eye and ear; or indeed for any adaptation at all. It is obviously impossible, as we have seen, that they can have been produced by any process of self-adaptation. We have argued in the foregoing Chapters that complex adaptation is beyond the power of natural selection to produce, even in geological time; and that there are many instances of structure being produced in anticipation of function—that is to say, before they could be useful—which it is obvious that natural selection can have no tendency to do. If these conclusions are established, no explanation of them appears possible except the old one, that the process of organisation has been guided by Intelligence.

This does not contradict natural selection.—This does not in any degree set aside the law of natural selection; on the contrary, it shows how the variations are produced which are to be selected and preserved. Selection can originate nothing; it presupposes variation; and the action of formative Intelligence in the origin of species is by "guiding variation along beneficial lines" (to quote, I believe, Asa Gray's expression); or, as it may be otherwise expressed, formative Intelligence appears as a law which directs, not fortuitously or at random, but according to a predetermined plan, the occurrence of the variations whereby new orders and classes are formed; and, especially, it introduces a distinct principle of correlation, by determining those variations to occur together whereof the co-operation is needed towards one result.

Origin of the Bird's wing.—Formative Intelligence, however, does not appear to act uniformly or constantly. We have seen that when one part of the organism varies, other parts do not always vary so as to produce perfect adaptation.[1] Perhaps, indeed, no adaptation is absolutely perfect; it is probable that the perfectionment of such organs as the eye and the ear has in all cases been a slow process, and we cannot doubt that this

[1] See p. 173.

is true of the brain. But if sudden variation is consistent with the laws of life, as we have seen to be almost certainly the case; and if there is a Formative Intelligence, determining the variations that are required, and preparing structure in anticipation of function; there will be nothing contrary to the laws of life in the sudden origin of a complexly adapted structure. It appears probable that the origin of the Bird's wing is such a case. The arrangement of the feathers with their fringes, for the purpose of flight, is a case of complex adaptation.[1] It appears impossible that any such arrangement in nascent or ungrown wings could have been of any service to their possessors; and there is consequently no presumption against its having originated suddenly. But if its origin has been gradual, this is a case of structure in anticipation of function, and is thus an equally good instance of the effect of Formative Intelligence.

Materials supplied by Habit and modified by Intelligence.—We have seen that in many cases the details of a type are adhered to, while it is modified so as to adapt it to the most different purposes.[2] Thus in comparing with each other the Man's hand, the Dog's foot, the Bat's wing, and the Whale's paddle, we find that the bones correspond in respect of position and connexion, though changed in form and size. In tracing such adaptive modifications, it seems as if an intelligent agency were adapting materials given to it by an unintelligent one; and this I believe to be the actual fact. The unintelligent power is hereditary habit; the intelligent power is the Formative Intelligence which guides the process of organic evolution. For, though Intelligence is co-extensive with life, it is not meant that all the laws of life are to be referred to vital Intelligence. Habit also is a law of life and co-extensive with life, but Habit and Intelligence are distinct principles.

Intelligence is co-extensive with life, but most discernible in the highest life.—Intelligence is probably at work in every vital

[1] See the description of the mechanism of the Bird's flight in the Duke of Argyll's *Reign of Law*.

[2] See pp. 225, 226

process whatever, but most discernibly in the highest. In every vital action, whether formative, motor, or sensory, whether conscious or unconscious, the ordinary forces of matter are at work directed and controlled by life and Intelligence. But, though these two sets of causes act in every manifestation of life,—the forces of inorganic matter on the one hand, and life with Intelligence on the other,—it is a mere statement of obvious fact to say that the inorganic causes are most discernible in the lower vital functions, as in nutrition and respiration; and that life and Intelligence are most discernible in the formation and the action of the organs of sense and of thought. This is only saying in other words, what we have said before, that Purpose is most traceable where Causation is least so.[1]

This does not contradict Evolution.—There is nothing in all this inconsistent with the doctrine of Evolution. The doctrine of Evolution is true; but it explains nothing, because it is not a primary law, but only a resultant effect from a great variety of causes; and if the reasoning of the present work is correct, Intelligence is one of these.

In the next chapter we shall have to consider the nature of vital Intelligence; and this will open the question of the relation between the bodily and the mental life.

NOTE.

LEWES ON THE ORIGIN OF SPECIES.

Lewes's Rejection of Darwin's Theory.—In reading Lewes's *Physical Basis of Mind*, I have been surprised to find that his criticism on Darwin's theory amounts to a rejection of it as complete as my own. I quote his words, italicising some of them:—

Quotations.—"At each stage of differentiation there has been a selection, but we cannot by any means say that this selection was determined by the

[1] See p. 51.

fact of its giving the organism a superiority over rivals, inasmuch as *during all the early stages, while the organ was still in formation, there could be no advantage accruing from it.* One animal having teeth and claws developed will have a decided superiority in the struggle over another animal that has no teeth and claws ; *but so long as the teeth and claws are in an undeveloped state of mere preparation, they confer no superiority.*"—P. 110.

"The sudden appearance of new organs, not a trace of which is discernible in the embryo or adult form of organisms lower in the scale,—for instance, the phosphorescent [organs of such insects as the glow-worm] and electric organs [of some fishes]—is like the sudden appearance of new instruments in the social organism, such as the printing-press and the railway, *wholly inexplicable on the theory of descent*, but is explicable on the theory of Organic Affinity."—P. 117.

"*Organic Affinity*" *explains nothing.*—The expression "organic affinity" has been invented, I believe, by Dr. Freke. It seems to be a mere synonym for organising power,—it explains nothing, and suggests a misleading analogy with chemical affinity. The above quoted remarks, on the insufficiency of hereditary transmission and natural selection to account for the facts of the organic world, are, however, valuable.

CHAPTER XXII.

INTELLIGENCE.

Formative, motor, and mental functions, all guided by Intelligence.—We have seen[1] that vital functions are to be classed as formative, motor, and sensory;—sensation develops into mind; and we shall here speak of functions as formative, motor, and mental.

Formative, motor, and mental functions are all guided by Intelligence. We have endeavoured to show that formative or organising Intelligence is an ultimate and inexplicable fact; and in what follows we take this as proved.

Unconscious instructive Intelligence. The Bee.—Those who believe that the complexities of organisation are due to unconscious Intelligence, will probably feel no difficulty in believing the same of such motor instincts as the cell-building powers of the Bee and the Wasp. These insects, in building their hexagonal cells, are manifestly guided by Intelligence of some kind; but it is not conscious Intelligence, for we cannot think that they have any conscious knowledge of those properties of the hexagon which make that form the most suitable to their purposes. The unconscious Intelligence that guides the Bee in building its cell is the same in kind with the unconscious Intelligence that determines the formation of its mouth and its eyes. The only reason why we think there is anything specially wonderful in such instincts, is that they are comparatively

[1] See p. 85.

uncommon. Motor instincts so definitely adapted as these to a special purpose, are found in comparatively few out of the vast number of animal species, while every animal that has well-developed eyes, presents an instance of the adaptation of means to purpose by unconscious Formative Intelligence, quite as definite as that shown in any motor instinct, and far more subtle. Considered without reference to its being exceptional or common, the Bee's eye, and its mouth, are more wonderful than its cell.

These instincts are the most extreme case of definite motor actions directed by an intelligent and yet unconscious purpose. But they are distinctly exceptional; and in order to understand the relations between the conscious and the unconscious functions, we must take an instance, not from the most exceptional, but from the commonest cases.

Gradation between Conscious and Unconscious Action. The Eye and the Digestive System.—There is no clearer instance of adaptation than the structure of the iris, enabling it to contract, involuntarily and unconsciously, in order to protect the retina against too much light. The structure of the iris is a case of unconscious Formative Intelligence, and its action in closing against the light is a case of unconscious motor Intelligence. The action of the iris in closing is as purely unconscious as any formative action; it is not under the control of the will, it is not accompanied by consciousness, nor does it necessarily depend on sensation; for there is a kind of blindness in which the optic nerve does not transmit the sensation of light to the brain, and yet the iris opens and closes as in a healthy eye.[1] From this there is a perfect gradation to those motor actions which are accompanied by consciousness and directed by the will. The action of the eyelids in closing is sometimes voluntary, but is oftener performed spontaneously, without consciousness or will. The motion of the eyeballs is more decidedly under the control of the will than that of the eyelids. And, to complete the

[1] Carpenter's *Human Physiology*, p. 683.

evidence of a perfect gradation between the involuntary and the voluntary actions, it is asserted that in some few men the iris is capable of being opened and closed at will.[1] We find the same gradation between the unconscious and the conscious actions in the digestive system also. The muscular action of the stomach is as involuntary as the secretion of the gastric juice, and in a state of health it is unaccompanied by sensation. The action of the throat in swallowing is involuntary, though accompanied by sensation. The action of the mouth in chewing and swallowing is mostly guided by sensation, with little direction from the will. And lastly, the action of the hands in carrying food to the mouth is altogether voluntary.

In the cases of the motor actions of the eye and of the digestive organs, each distinct action has its own separate set of muscles. But this is not true of all motor actions. Coughing and sneezing, for instance, have no special muscles for their performance, though they have a definite purpose, namely the removal of obstructions from the air-passages. These, like the closing of the eyelids, are performed in obedience to sensation, and are only in part under the control of the will.

Reflex, Consensual, and Voluntary Action are all Intelligent, though not all Conscious.—We thus see that there is a perfect gradation from those motor actions which are neither concious nor voluntary, through those which are guided by sensation with little control from the will, to the purely conscious and voluntary ones. We have in a previous Chapter enumerated these as respectively reflex, consensual, and voluntary; [2] but we have here to insist on the truth that although they differ as regards their dependence on sensation and will, they are all alike guided by Intelligence. The muscular actions at the

[1] "There are men who have learned how to contract the iris. The celebrated Montana had this power, which is possessed also by a medical man now living at Kilmarnock—Dr. Paxton—a fact authenticated by no less a person than Dr. Allen Thomson."—Lewes's *Physical Basis of Mind*, p. 370. Mr. Lewes also mentions (p. 371) that some persons have possessed the power of checking the action of the heart at will.

[2] See p. 84.

unconscious end of the scale are determined by the same Intelligence that organises the muscles each for its special work;—the iris is determined to close, not by any conscious Intelligence, but by the same unconscious Intelligence that formed it for

Gromia, with extended pseudopodia. From Carpenter's *Mental Physiology*.

closing. The muscular actions at the other end of the scale, on the contrary—the motions of the artist's hand, for instance—are directed by conscious mental Intelligence. There is consciousness at only one end of the scale, but there is Intelligence throughout.

Carpenter on Unconscious Intelligence in Rhizopods.—We have seen that among the lowliest organisms, which have scarcely any structure, actions are observed that constitute a kind of transition between the motor and the formative functions, such as the stretching forth of pseudopodia or temporary tentacles.[1] From our present point of view, it is important to observe that actions of this class are in some cases as definitely and as discernibly guided by Intelligence as any of the formative or the motor functions of much higher organisms. "We can scarcely conceive that a creature of such simplicity (as a Rhizopod) should possess any distinct consciousness of its

Amœba in different forms; A, B, C. From Carpenter's *Mental Physiology*.

needs, or that its actions should be directed by any intention of its own; and yet (Dr. Carpenter) has lately found results of the most singular elaborateness to be wrought out by these minute 'jelly-specks,' which build up 'tests' or casings of the most regular geometrical symmetry of form, and of the most artificial construction. Suppose a human mason to be put down by the side of a pile of stones of various shapes and sizes, and to be told to build a dome of these, smooth on both surfaces, without using more than the least possible quantity of a very tenacious but very costly element in holding the stones together.

[1] See p. 86.

If he accomplished this well, he would receive credit for great intelligence and skill. Yet this is exactly what these jelly-specks do on a most minute scale; the tests they construct when highly magnified, bearing comparison with the most skilful masonry of man. From the same sandy bottom one species picks up the coarser quartz grains, cements them together with phosphate of iron secreted from its own substance, and thus constructs a flask-shaped test having a short neck and a single large orifice. Another picks up the finest grains, and puts them together with the same cement into perfectly spherical tests of the most extraordinary finish, perforated with numerous small pores at regular intervals. Another selects the minutest sand-grains and the terminal portions of sponge-spicules, and works these up together,—apparently with no cement at all, by the mere laying of the spicules,—into perfect white spheres, like homœpathic globules, each having a single fissured orifice. And another, which makes a straight many-chambered test, that resembles in form the many-chambered shell of an Orthoceratite,[1]—the conical mouth of each chamber projecting into the cavity of the next,—while forming the walls of its chambers of ordinary sand-grains rather loosely held together, shapes the conical mouths of the successive chambers by firmly cementing together grains of ferruginous quartz, which it must have picked out from the general mass." [2]

These Facts cannot be referred to Unintelligent Agencies.—It would be difficult to imagine any clearer proof of unconscious Intelligence than these, especially the last; and they appear inexplicable as results of either self-adaptation or natural selection. They would be so even if this architectural power were

[1] A fossil many-chambered shell belonging to the Cephalopoda, and resembling the Nautilus except in being not spiral but shaped like a "straight horn," whence its name.

[2] Carpenter's *Mental Physiology*, p. 41. The illustrations show only the want of definite form and structure in Rhizopods. *Gromia* secretes its shell like a Mollusc, and *Amœba* has no shell.

possessed by only one species; but the difficulty of so explaining them is greatly, perhaps we may say indefinitely, increased by the variety of the structures.

Summary.—The proof of Intelligence is adaptation to purpose, and we have seen that organisation and motor action alike manifest Intelligence. This is no new discovery;—but we have also seen that motor action may, by this criterion, be perfectly intelligent without being in any degree conscious; and moreover, that the simplest organisms perform actions which are truly intelligent, and which constitute a transition between the motor and the formative functions.

Identity of Organising and Mental Intelligence.—For the reasons now stated, we conclude that vital Intelligence is the same throughout;—in other words, that the unconscious Intelligence which directs the formation of the organic structures is the same which becomes conscious in mental action. The two are generally believed to be distinct;—conscious mental Intelligence is believed to be human, and Formative Intelligence to be Divine. This view leaves us room for the intermediate region of instinct; and hence the marvellous character with which instinct is generally invested. But if we admit that all the Intelligence manifested in the organic creation is fundamentally the same, we shall reasonably expect to find such a gradation as we actually witness, from perfectly unconscious to perfectly conscious Intelligence;—the intermediate region being occupied by intelligent but unconscious motor action—in a word, by Instinct.

If it is true, as here maintained, that the Intelligence which adapts organic structures to their functions is fundamentally identical with that which becomes conscious in the mind, it follows from the mere statement, that the Intelligence which forms the lenses of the eye is the same which, in the mind of Man, has discovered the theory of the lens;—the Intelligence that hollows out the bones and the wing-feathers of the Bird

in order to combine lightness with strength, and places the feathery fringes where they are needed for the purpose of flight, is the same which, in the mind of the engineer, has devised the construction of iron pillars hollowed out like these bones and feathers;—and the Intelligence that guides the Bee in its unconscious shaping of its hexagonal cells, is the same which, in our minds, understands the properties of the hexagon.

This view is well known among the Germans, and is beginning to be known among us; but most English-speaking people have been accustomed to refer all organic adaptations to Creative Wisdom directly. This was almost inevitable for believers in a Divine Creator, so long as the world and all that it contains was supposed to have been created in a few days. But now that the doctrine of Evolution has been sufficiently established, it appears more reasonable to believe that organic progress has been effected, not by a fresh exertion of Creative Power at every one of its innumerable stages, but by a principle of Intelligence which guides all organic formation and all motor instincts, and finally attains to consciousness in the brains of the higher animals, and to self-consciousness in the brain of Man.

Difficulties lessened by this View. Imperfections of Organisation.—When rightly considered, the view of direct creation will appear untenable. It cannot be reconciled with the imperfections of the organic world, and the slow and interrupted progress towards relative perfection. And absolute perfection is not always attained, even in nature's highest work. The human eye, even when healthy and normal, is asserted by Helmholtz to be very imperfect in comparison with the best optical instruments that human skill can produce.[1]

Parasitic Worms.—But these are the smallest of the difficulties of the old view. I refer especially to the existence of such organisms as parasitic worms, which are well adapted for

[1] See also a paper "On the Imperfections of the Normal Human Eye," by Henry Burden, M.D., in the *Proceedings of the Belfast Natural History Society for* 1873–4.

their mode of life, but have probably no sensation and certainly no consciousness, yet inflict pain, disease, and death on sentient and conscious animals. On the theory of the independent creation of every separate species, these can only be regarded as instruments of torture devised by Creative Wisdom. But if we believe that they are descended from species which were not parasitic, and have become self-adapted to new habitats, their existence is only a particular case of the question why pain and disease are permitted at all.

Immoral Instincts.—The same is true of what have been called unnatural, and may almost be called immoral instincts; such as the working Bees slaughtering the drones after the queen has been fertilised; the habit of some species of Ants of carrying off Ants of other species while in the pupa state, and making slaves of them; the Cuckoo's habit of laying its eggs in the nests of other birds, and the young Cuckoo throwing the original tenants out of the nest to perish. It is easier to believe these instincts to be peculiar and abnormal results of vital Intelligence, than to believe each of them to be a special Providential endowment.

This View does not contradict Theism.—The view here maintained may be called Pantheistic. The proper meaning of Pantheism is the identification of the Divine Power and Intelligence with the powers and intelligences that work in the world of matter and mind. I am not a Pantheist; on the contrary, I believe in a Divine Power and Wisdom infinitely transcending all that can be known to us in our present state of being. The following will be sufficient to show that my position is consistent with Theism.

Matter has been endowed with gravitative and chemical forces which are capable of producing motion. When a mass moves, as in the fall of a stone, or when a fire burns and produces heat, which is atomic motion, the energy of the motion is neither brought from without nor created at the moment

it only becomes actual or active from being potential or latent;—there is not a fresh exertion of Divine Power whenever a stone falls or a fire burns. So with Intelligence. All Intelligence is a result of Divine Wisdom; but there is not a fresh determination of Divine thought needed for every new adaptation in organic structure, or for every original thought in the mind of Man. Every one will admit that there is not a fresh act of creation when a new individual is born;—I say the same of the origin of species and of classes.

Vital Intelligence guides Organic Action for the Health of the Organism. Disease.—In conclusion, we have to consider the law under which vital Intelligence acts. This is only capable of being very indefinitely stated. The law of all its action, whether formative, motor, or mental, is that it tends to whatever is favourable to the life and health of the organism. If there are any exceptions to this law, they are in disease; but there are at least some cases of disease which are rather cases of it than exceptions to it. All eruptive diseases are probably due to an instinctive vital action endeavouring to get rid of poisonous matter. And morbid growths, like cancer, probably consist of portions of the organism that have got away from the control of the general life, and lead a life of their own parasitic on the rest, and ministering to their own life though to the injury of the entire organism.[1]

Vital Action ministers to the Race as well as to the Individual.—The law that the actions of every organism are such as to minister to its own life and health, is to be understood with this very important extension, that under certain circumstances it ministers not to its private advantage only, but to that of the race. This is the ground of the reproductive and maternal functions; and, where vital actions are accompanied by sensation and consciousness, this is the ground also of the sexual, the domestic, and the social affections.

[1] See p. 78, note.

CHAPTER XXIII.

INSTINCT.

In the foregoing Chapter we have advanced the view that formative, motor, and mental action are all equally intelligent, and that the Intelligence which guides them all is the same. We have consequently rejected the common view, which regards organising Intelligence as altogether distinct from mental Intelligence, and looks on the intermediate region of Instinct as not only mysterious but anomalous.

I maintain that Intelligence is not a resultant from Unintelligent Agencies.—The disciples of Darwin and Spencer will probably agree in rejecting the common view, and in believing that there is no fundamental difference between the agencies which guide the three several manifestations of life which we may briefly call Organisation, Instinct, and Thought. But I am altogether at issue with them as to the ultimate nature of those agencies. They believe that Adaptation, Purpose, or Intelligence, in all these manifestations, is a resultant from unintelligent laws and forces;—I think it is an ultimate fact. In some of the foregoing Chapters we have argued for the ultimate nature of the organising Intelligence, maintaining that it cannot be resolved into self-adaptation and natural selection. In the present Chapter we have to maintain the same of instinctive or motor Intelligence.

Darwin's attempt to account for Instinct by Natural Selection. Difficulty about Neuter Insects.—Darwin endeavours to account

for instinct, as for most of the facts of life, by natural selection. Concerning the constructive instincts of social Insects,—Bees, Wasps, and Ants,—there is this peculiar difficulty, that they cannot be inherited in the direct line, because the working insects, which alone possess those wonderful instincts, have their reproductive organs undeveloped, and cannot propagate; so that the survival or destruction of the working insects of any generation cannot affect the character of the next generation; and accumulation through hereditary habit, which has been the chief agency in forming the almost equally wonderful artificial instincts of the pointer and the sheep-dog, can have no place here, just as modifications of character acquired in a man's education and his subsequent life, though they may be transmitted to his sons, cannot be transmitted to his nephews.[1] Darwin says that this difficulty at first seemed to him a very formidable one in the way of the entire theory of natural selection; but he replies to it, that the principle of competition, and natural selection as its result, is applicable to families as well as to individuals. He believes that the cell-building instinct of the Bee, for instance, has been perfected by the survival of those swarms which constructed the most perfect hexagons, and consequently used their wax the most economically. This explanation postulates, what is certainly probable, that the same variation will affect all, or the great majority, of the bees of the same swarm.

It cannot be denied that natural selection may act in this way; so that in the case of neuter or non-sexual working insects, though there can be no effect whatever from habit accumulating in force through descent, there may be an accumulated effect from natural selection. Nevertheless it is scarcely possible to accept this as a satisfactory account of the way in which the wonderful instincts, not only constructive but social, of the Bee have been perfected. We have seen that improvement by the Darwinian process needs an almost infinite number

[1] It has been truly remarked, that this is a complete refutation of Lamarck's theory of all function and structure having their origin in hereditary habit.

of individuals, first, in order to afford the necessary chances of variable variations, and secondly, in order to eliminate the effect of "fortuitous destruction."[1] If natural selection is applied in this way to Bees and other social insects, the unit on which the forces of variation and selection act is not, as in all other cases, the individual, but the swarm;—the swarm, for this purpose, takes the place of the individual;—and as the swarm, when it has grown into a colony, includes hundreds or thousands of insects, the number of individuals whereon these forces are to act is diminished in the inverse proportion, and the efficiency of natural selection indefinitely weakened.

It may be said in reply, that natural selection will act more surely, and with less counteraction from "fortuitous destruction," on comparatively large masses, like swarms, than on individuals; and there is probably some force in this. But though this may give a greater chance of the preservation of favourable variations when they occur, it will not compensate for the smaller number of favourable variations that will occur when the unit is not the individual but the swarm.

Special Instincts are a parallel difficulty to Special Organic Adaptations.—Except for the special difficulties now pointed out, the difficulty of accounting for the origin of special instincts by the Darwinian theory is exactly similar to that of accounting for organic adaptations. There are very many instincts among animals for the origin and perfectionment of which it is scarcely possible to account; such as the nest-building instinct which is general among birds, and exists among some fishes. It would require a volume to describe all the strange instincts known to exist, and mostly connected with the duty of providing for the young; and it is the less needful, because there are few branches of biological science so well known to most readers. One only I will mention here; namely, the habit of the male of some fishes to take the eggs into his mouth, and carry them about until they are hatched. This habit is a case

[1] See p. 185 *et seq.*

of "independent similarity," because it is a character of isolated genera belonging to different families, among which it must have been independently evolved. The origin of special instincts like these is confessedly a difficulty in the way of Darwinism, but it is neither a greater nor a less difficulty than that of accounting for such special structures as the electric organs of some fishes;—a case which Darwin mentions as one of special difficulty. It is to be observed that this also is a case of "independent similarity;" the Gymnotus and the Torpedo are not nearly allied; their electric organs have no close resemblance, and have been separately evolved.

Herbert Spencer on Instinct—We may here remark, that although Herbert Spencer, in the first volume of his *Psychology*, has made a most ingenious and elaborate attempt to account for the nervous structure and the entire motor and mental life of animals by the single principle of self-adaptation, continued and accumulated by hereditary habit and assisted by natural selection, he has made no attempt whatever to show how special instincts are to be explained in this way.

Instinctive Actions of Rhizopods.—From these let us go back to the simplest of all motor instincts;—for instance, the action of an *amœba* or *gromia*—mere little masses of vitalised jelly, having motor powers but no structure—in putting out pseudopodia and inclosing its food. The food-seeking instinct appears to be the commonest and most primary of all. Plants have it, though they show it in a different way, yet perhaps not essentially different, by sending out shoots towards water or manure. It appears impossible to account for this instinct except as an ultimate property, characterising living as distinguished from dead matter. Were it witnessed only among unconscious plants and equally unconscious Rhizopods, we might think it comparable to electric or magnetic attraction. But we cannot doubt that it is the same impulse which, in the higher animals, develops into the conscious desire and search for food.

We have mentioned in the previous Chapter[1] the wonderful instinct of some Rhizopods in building their shells. This also appears impossible to account for as the result of habit. The food-seeking instinct is much less wonderful, but we dwell on it here in consequence of its elementary character and its universality.

Instincts of Spermatozoa and Planulæ.—We may mention, as similar cases to food-seeking instinct, the action of spermatozoa in rushing towards the ovum; and, what is still more remarkable, the apparently intelligent action of Planula larvæ.[2] Prof. Hincks says, in writing of the Discophorous Medusæ:—

"After a term of free existence the Planula selects a site for permanent settlement. This process of selection, often conducted with much apparent fastidiousness, may be witnessed in the case of the embryos of fixed animals generally." [3]

Self-guidance proves Intelligence.—It seems impossible that such actions as these can be other than primary;—in other words, it appears impossible that they can be accounted for, as Herbert Spencer would do, by the result of any acquired and inherited habit of responding to stimuli. And if self-guided actions like these are not acquired but primary, then Intelligence is a primary and not a secondary endowment; for nothing can be a clearer proof of Intelligence than the power of self-guidance.

Motor Instincts of the Frog.—The instincts now mentioned are among the simplest. If it is true, as we maintain, that in the simplest instincts there is an element of Intelligence not derived from Habit, the same cannot be doubted of the more complex instincts of the higher animals; but their complexity makes it difficult to reason about them. Among these there are, however, some cases where we may say with certainty that particular

[1] See p. 409. [2] See p. 335.
[3] *Popular Science Review*, vol. x., 1871.

actions cannot be the results of habit, because there has not been anything in the experience of either the individual or the race which can have led to the animal's acquiring the power of performing them. In more familiar language, they cannot have been learned by either the individual or its ancestors, because there were no circumstances that could have taught them. Habit is only the law that all actions tend to be repeated, and all characters to be perpetuated; and if an animal performs an action suited to circumstances for which there is no precedent in the history of its race, this is proof of the existence of an Intelligence which is not due to the law of Habit.

Thus, if the skin of a frog's side is irritated with a drop of acetic acid, the frog will wipe off the acid with its nearest foot. This may perhaps be an action which the frog has learned in the ordinary experience of the race;—I do not know whether this is so or not, but it may be liable to annoyance from small insects, and accustomed to rub them off with its feet. But if the nearest foot is held, so that it is not available for the purpose, the frog will use the other foot. Now, this is an action for which there can be no precedent in the life of the species;—it is impossible that it can ever happen to the frog in a state of nature to attempt to use one foot for such a purpose, to find it held, and to use the other foot instead. If the action of the frog's foot in wiping off disturbing objects were purely habitual, without any element of Intelligence, then, as habit consists in doing what has been done before, it could use only the nearest foot for the purpose;—the employment of the other foot, being unprecedented in the experience of its race, could not occur under the law of Habit, and consequently could not occur at all. To use one leg when the other is held is no doubt a lowly instance of Intelligence, but without Intelligence it could not be done.

The frog presents us with another instance of a power which cannot be the result of any experience, either individual or ancestral. If a frog is placed on the hand or on the back of a book, and if this unaccustomed perch is moved from side to side, the

frog will endeavour, with considerable success, to keep its balance and preserve itself from falling. There is nothing in the experience of the species which can have produced this power, because it is one which it never called into action when in a state of nature; and we infer, by the same reasoning which applies to the previous case, that it is due to a primary endowment of intelligence, not resolvable into the result of habit.—In cases like these, it is obvious that the same circumstances which exclude the agency of ancestral experience and accumulated habit, also exclude that of natural selection, because a power which is never needed during the ordinary life of the organism will not be preserved by selection.[1]

Instinct of Bees.—Another and a much more remarkable instance of a faculty which can be due only to Intelligence is shown in a well-known experiment of Huber's on Bees. He placed some humble bees under a bell-glass with a piece of comb which was too uneven in shape to stand firm, and the bees built little pillars or buttresses of wax under it in order to keep it firm. It is impossible that these circumstances can have occurred often enough in the history of species to produce this instinct, as a result of either hereditary habit or natural selection.

The Duke of Argyll on the Instinct of the Wild Duck.—But the following is the most wonderful instance that I can find of a faculty which cannot be due to the experience of the race:—

"In walking along the side of a river with overhanging banks, I came suddenly on a common wild duck (*Anas boschus*) whose young were just out. Springing from under the bank, she fluttered out into the stream with loud cries and with all the struggles to escape of a helplessly wounded bird. To simulate the effects of suffering from disease, or from strong emotion, or

[1] These facts about the motor instincts of the frog are stated on the authority of Prof. Huxley's paper on "Animal Automatism" in the *Fortnightly Review* of November 1874.

from wounds upon the human frame, is a common necessity of the actor's art, and it is not often really well done. The tricks of the theatre are seldom natural, and it is not without reason that 'theatrical' has become a proverbial expression for false and artificial representations of the realities of life. It was therefore with no small interest that on this, as on many other occasions, I watched the perfection of an art which Mrs. Siddons might have envied. The laboured and half-convulsive flapping of the wings, the wriggling of the body, the straining of the neck, and the whole expression of painful and abortive effort, were really admirable. When her struggles had carried her a considerable distance, and she saw that they produced no effect in tempting us to follow, she made resounding flaps upon the surface of the water, to secure that attention to herself which it was the great object of the manœuvre to attract. Then, rising suddenly in the air, she made a great circle round us, and returning to the spot renewed her endeavours as before. It was not however necessary, for the separate instinct of the young in successful hiding effectually baffled all my attempts to discover them."

"It is not really conceivable that wild ducks have commonly many opportunities of studying each other's action when rendered helpless by wounds, nor is it conceivable that such study can have been deliberately made even when opportunities do occur. When one out of a flock is wounded all the others make haste to escape, and it is certain that this trick of imitated helplessness is practised by individual birds which can never have any such opportunities at all. Moreover, there is one very remarkable circumstance connected with this instinct, which marks how much of knowledge and of reasoning is implicitly contained within it. As against man the manœuvre is not only useless but it is injurious. When a man sees a bird resorting to this imitation, he may be deceived for a moment, as I have myself been, but his knowledge and experience and reasoning faculty soon tell him, from a combination of circumstances, that it is merely the usual deception. To man therefore

it has the opposite effect of revealing the proximity of the young brood, which would not otherwise be known. I have frequently been led by it to the discovery of the chicks. Now, the most curious fact of all, is that this distinction between man and other predacious animals is recognised and reflected in the instinct of birds. The manœuvre of counterfeiting helplessness is very rarely resorted to except when a dog is present. Dogs are almost uniformly deceived by it. They never can resist the temptation presented by a bird which flutters just in front of their nose. It is therefore almost always successful in drawing them off and so rescuing the young from danger. But it is the sense of smell, not the sense of sight, which makes dogs so specially dangerous. The instinct which has been given to birds seems to cover and include the knowledge that as the sense of smell does not exist to the same extent in man, the mere concealment of the young from sight is ordinarily as regards him sufficient for their protection; and yet I have on occasion seen the trick resorted to when man only was the source of danger, and this by a species of bird which does not habitually practise it. This was the case of a blackcap (*Sylvia atracapilla*) which fell to the ground, as if wounded, from a bush, in order to distract attention from its nest."[1]

The Duck's Intelligence is rather Rational than Instinctive.—It appears to be clearly proved in the foregoing extract that this extraordinary power cannot be due to habit, and natural selection seems equally out of the question;—such a power as this could not arise by mere spontaneous variation, and selection cannot originate anything, but only preserves useful variations as they arise. This power, indeed, can scarcely be called instinctive. Instinct is best defined as unconscious motor Intelligence, but this appears to be fully conscious, and to depend on consciousness. It appears to differ in no discernible way from the conscious reason of Man.

[1] "Animal Instinct in relation to the Mind of Man," by the Duke of Argyll, *Contemporary Review*, July 1875.

Mr. Lewes on Habit and Intelligence as Vital Properties.—Here the present Chapter might conclude. I believe the evidence now adduced proves what I have undertaken to prove, namely, that Instinct contains an element of Intelligence which cannot be resolved into Habit or accounted for by natural selection. But, inasmuch as the subject is not familiar, and it is the purpose of this entire work to insist on the distinction between Habit and Intelligence, I will go on, at the risk of some repetition, to show farther that it is real, and that I am not merely disputing about words and names. This is the more necessary, because so clear and accurate a writer as Mr. Lewes has apparently failed to perceive the distinction. In arguing against a merely mechanical view of life, he says:—

"An organism is radically distinguishable from every inorganic mechanism, in that it acquires, through the very exercise of its primary constitution, a new constitution with new powers." [1]

This is a recognition of the law of Habit, in virtue of which actions tend to repeat and perpetuate themselves; so that two precisely similar organisms, if placed in different circumstances, will become unlike, through the habit of making different responses to different stimuli. And it is also a recognition of the important truth, at which we have arrived by a different process,[2] that Habit is a vital and not merely a mechanical law;—an agency which can exist only in living beings. But Mr. Lewes, farther on, asserts the fact of vital Intelligence, without appearing to perceive that it is something more than is implied in Habit.

"The organism is variable, self-regulating, incalculable. It has *selective adaptation*, responding readily and efficiently to novel and unforeseen circumstances; acquiring new modes of combination and reaction. An automaton that will learn by experience, and adapt itself to conditions not calculated for in

[1] Lewes's *Physical Basis of Mind*, p. 325.
[2] See pp. 48, 90.

its construction, has yet to be made;—till it is made, we must deny that organisms are machines."[1]

Distinction between Habit and Intelligence.—This is true; but what we seek to insist on is this, that it goes beyond the truth stated in the former-quoted paragraph. *Selective adaptation* is more than a mere capacity of the organism for modification under the law of Habit;—the power of "selective adaptation to novel and unforeseen circumstances" is Intelligence, and is not implied in the mere capacity for modification.

[1] *Physical Basis of Mind*, p. 385.

CHAPTER XXIV.

CONSCIOUSNESS.

Mind is developed out of Sensation, but Sensation alone does not Constitute Mind.—In the foregoing Chapters we have endeavoured to trace the relation of Habit and Intelligence to each other in the unconscious life, both organic and motor. Before we go on to trace the same relation in the conscious or mental life, we have to take note of a few primary facts respecting the nature of Mind.

Mind begins from sensation and is developed out of sensation. But sensation alone does not constitute Mind;—something more is needed, and this something is Consciousness.

Distinction between Sensation and Consciousness. Unconscious Sensation.—The primary consciousness is consciousness of sensation. We must distinguish between sensation and consciousness of sensation;—it is possible to have a sensation without being conscious of it. This is not a very familiar truth, because the absence of consciousness is not likely to be noticed; but it must have occurred to every one to become suddenly conscious of a sight that had been before his eyes, or of a sound that had been in his ears, for some time; and to remark, "I saw, or heard, this without being aware of it." But the most conclusive proof of the distinctness of consciousness from sensation is afforded by some of the facts of sleep and awakening. We cannot think that in sound sleep there is any consciousness of sensation; yet when any one has fallen asleep in a loud monotonous noise, a sudden cessation of the noise will

awaken him, just as its sudden commencement would do if he had fallen asleep in silence. This proves that the sound must have been heard, though the consciousness was asleep to it. Another instance of the same kind is the fact which we have mentioned in a former Chapter,[1] that it is possible to acquire the habit either of waking up at a particular sound, such as that of a bell, or of disregarding it and sleeping through it.

Consciousness is not limited to Sensation.—We thus see that there may be sensation without consciousness, but there can be no consciousness without sensation. Consciousness would never come into existence if it were not awakened by sensation. The conscious or mental life is developed out of the merely sentient life, as the sentient life is developed out of the insentient. But when consciousness is thus generated, feelings arise in consciousness which are not directly produced by sensation;—the most elementary of these are probably the feelings of hope and fear.

The Pleasures of Beauty and of Music belong not to Sensation but to Consciousness.—The feelings of pleasure due to visual beauty and to music are also, for the most part, not pleasures of mere sensation, but are produced in the consciousness. The pleasures due to single soft or bright colours and to single sweet tones are probably pleasures of mere sense; but these form an almost infinitesimally small portion of the complex and varied delight due to sight and sound.

The senses of sight and hearing are the only senses which minister to the intellect in any high state of intellectual development; and, no doubt for this reason, they are the only æsthetic senses—that is to say, the only senses through which we derive any ideas of beauty. It may be unusual to call that *beauty* which we admire and enjoy in music, but it certainly impresses the mind exactly as visual beauty does, making allowance only for the unlikeness of one sense to another.

[1] See p. 97.

Why the effect of Music is more intense than that of Visual Beauty.—The objects of visual beauty are in general much more permanent than sounds can be, and they consequently give a more durable pleasure; but the pleasure due to music, on the other hand, is, while it lasts, more intense than that due to visual beauty. The reason of this no doubt is, that the beauty, or what is called by an expression which is scarcely a metaphor, the harmony, of form and colour is due to the combination of several distinct impressions on the sense of sight, which cannot be properly combined without a motion of the eye; and this occupies some little time; while the harmony of sound is due to the combination of distinct impressions on the sense of hearing, which combine in the consciousness of themselves, without any time being lost.

Acquired Tastes.—The distinctness of consciousness from sensation may be further illustrated by the fact that a sensation which is disagreeable at first, sometimes becomes agreeable when it has become familiar. Hence the common and yet remarkable fact of acquired tastes. We are not speaking of the feelings produced in consciousness by visual beauty, by music, or by poetry, but of tastes in the primary sense of the word. There are flavours of which the taste is disagreeable at first, but for which a liking is easily acquired. It can scarcely be believed that the flavour comes by repetition to produce a different sensory impression on the nerves of taste;—it is much more likely that the sensation itself continues to be the same, while the impression produced by the sensation on the consciousness becomes different.

Analogous Impressions from different Senses.—Another remarkable fact which has a kindred bearing to the last-mentioned is, that consciousness perceives analogies between the sensations of different senses, without the slightest approach to identity. Softness is a sensation of touch, yet we speak of soft colour. Sweetness is a sensation of taste, yet we speak of sweet

sound. It would appear that though sensations of different senses—soft objects of touch and soft colours, sweet tastes and sweet sounds—are totally unlike in so far as they are impressions of sense, yet there is a real similarity in the impressions which they produce on the consciousness.

Consciousness and Self-consciousness.—It must be observed that consciousness is not necessarily self-consciousness. When we come to the subject of Mental Development, we shall have to consider the distinction between primary consciousness, or consciousness of feeling, and secondary consciousness, or consciousness of self as having the feelings.[1]

[1] See Chapter XXVII. Prof. Ferrier, in his remarkable and most suggestive *Introduction to the Philosophy of Consciousness*, uses the word consciousness in the sense which I define as self-consciousness. He consequently denies consciousness to the higher animals, a distinction which I do not make ; but this is only a difference of definition.

CHAPTER XXV.

MENTAL HABIT.

We have employed several of the Chapters of this Work in endeavouring to prove that in the formative functions of the organic creation there is a principle of Intelligence, not resolvable into unintelligent elements; and in the Chapter on Instinct we have maintained the same of the motor instincts. We have next to show the same to be true of the mental powers: but Habit and Intelligence co-exist in all life, and before treating of Mental Intelligence we must speak of Mental Habit.

Impressions on Consciousness are either Sensory or Ideal.—We have seen that Mind begins from sensation, but sensation does not constitute Mind;—Mind cannot be said to exist until Ideas arise. Ideas may be defined as all those impressions on consciousness and thought which are due to memory or imagination, or other cause than immediate impressions of sense. All impressions on the consciousness, consequently, are either sensory or ideal. Sensory impressions are primary, ideal impressions are secondary.

The Origin of Ideas belongs to Habit.—In the first edition of the present work, I spoke of Mental Habit as synonymous with the Association of Ideas. This however is erroneous;—we must begin farther back. Ideas cannot be associated until they exist, and not only their association, but their first origin, are cases of the law of Habit.

Memory is fundamental in Mind.—In the constitution of Mind, Memory is fundamental, and the most elementary form of idea is a remembered sensation.

Impressions on Sense outlast their Cause.—It is a familiar fact that sensations often outlast their immediate cause;—thus, if we look at a very bright light, we continue to see it for several seconds after we close our eyes. This, no doubt, is due to the sensory nerves having been thrown into a state of vibration which continues after its cause is removed;—it is analogous to the vibration of a musical string continuing after it is struck, and probably has nothing to do with Habit or any other specially vital principle.

Impressions on Consciousness outlast Sensation.—It is equally true that the impression made by a sensation on the consciousness tends to outlast the sensation itself. In the foregoing Chapter we have spoken of the distinction between a sensation and the consciousness of the sensation. When we hear speech, the sound of every syllable and every letter constitutes a separate impression on the sense of hearing, and yet the meaning of every word constitutes a single impression on the consciousness;—this shows that the impression on the consciousness produced by each of the successive sounds must outlast the mere sensation of the sound, by a time which, however short, is not infinitesimally small; and the same is true of the complex impressions produced on the consciousness as we listen to music. This prolongation of the impression is probably due to some physical property of the nerves of the brain, which is the organ of consciousness, causing them to vibrate longer than the sensory nerves;—it has probably nothing to do with Habit, and it does not amount to Memory, but it is the germ out of which Memory is developed. Memory arises when consciousness, like that which, as we have seen, outlasts the sensation that called it forth, is reproduced by any other cause than the immediate

stimulus of sensation. In a word, Memory is reproduced Consciousness.

We have next to show how this is to be referred to the law of Habit.

Memory is Habit acting within Consciousness. Residua.—There is nothing resembling Habit in a string continuing to vibrate for some time after it is struck; but if it were possible so to construct a musical instrument that after any passage was played on it, it should acquire a property making the playing of the same passage easier than before, this would be Habit; and if it acquired the power of reproducing the same passage spontaneously and without being played on, this would be Memory, amounting to recollection. The conscious organism is like such an instrument. The law of Habit implies that no action, or change of state in an organism, can pass away leaving the organism altogether unchanged; the constitution of the organism undergoes at least an infinitesimal change, tending to perpetuate the state or to repeat the action;—in other words, every action or change of state leaves behind it in the organism what the Germans call a residuum, or trace. When these residua affect the unconscious and especially the motor life, they constitute what is usually called Habit;—when they affect the conscious life, they constitute Memory. In other words, Memory is Habit acting within the sphere of Consciousness. Memory consists in the tendency of the residua of former impressions, retained in virtue of the law of Habit, to return into consciousness. When they are recalled by the effect of association or suggestion, the action is called simply Memory; when they are voluntarily recalled, it constitutes Recollection.

Association of Ideas is a case of Habit.—We have next to treat of the Association of Ideas. Although, as we have seen, the Association of Ideas is not co-extensive with Mental Habit, yet it is a case of the law of Habit. This has not been generally seen, because psychology has been studied as a separate

science; but it becomes obvious when the phenomena of Mind are seen to be a part of the phenomena of Life.

Elementary Law of Association stated.—The elementary law of association may be thus stated:—When two feelings have been experienced together or in immediate succession, the recurrence of either of the feelings separately tends to recall to consciousness the memory of the other feeling; or, in fewer words and less technical language, feelings that have been experienced together tend to recall each other. Let us call two sensations, or groups of sensations, A and B, and let us call the consciousness of the two respectively a and b. If A and B have often occurred together or in immediate succession, a and b also will have occurred together or in immediate succession; and, in virtue of the law that all the actions of living beings tend to become habitual, a and b will acquire the habit of occurring together, and whatever produces the one will recall the other also. Or, to use an illustration instead of an algebraic statement: the sight of a man's face and the sound of his voice may become so associated together in the mind, that the consciousness, or memory, of the two may acquire a habit of always accompanying each other, so that the sight of the face will recall the voice into conscious memory, and the sound of the voice will recall the face.

We must here reply to a possible objection to thus regarding all association as a case of the law of Habit. It is beyond question that many associations, and those the most durable, are habitual; for instance, that vast network of associations between the sounds of words and their meanings which constitutes the knowledge of one's own language, has evidently been acquired by the habit of hearing and speaking the language, from a time before the earliest time that one can remember. But when we form the association between a word and its meaning, not by often hearing them conjoined, but by a single mental act, as we constantly do in learning a foreign language, it may be argued that this is not a case of habit, but

of a different mental law. This difference, however, is merely one of degree. The law of Habit is that actions tend to repeat themselves. All habits no doubt strengthen with repetition; but if an action tends to repeat itself without having been repeated more than once, this is no less truly a case of habit than if it became habitual after countless repetitions. Residua accumulate and traces deepen by continuing and repeating the impression, but no new psychological principle is introduced;—just as we introduce no new mechanical principle when we strike many blows on the head of a nail which cannot be driven home by a single blow. Many blows would fail to drive home the nail, if a single blow were altogether without effect; and many impressions on the perception would fail to leave a remembrance, if a single impression left no trace whatever on the memory.

Contiguity is the Primary Bond of Association.—Association, as we have explained it, is of that simplest kind which is called Association by Contiguity, wherein impressions recall each other only because they have been experienced together or in immediate succession; and it may be urged as an objection to the view of Association depending on the law of Habit, that it is not always produced by Contiguity, but that any relation whatever that the mind cognizes—resemblance, contrast, or causation—may be a bond for the Association of Ideas. This is true;—when the power of cognizing any relation is acquired, that relation is capable of becoming a bond of association. This fact does not appear to need any special explanation. But Association by Contiguity is not only the primary fact, but by much the most important one. It would be possible for mental life to be developed without any power of forming associations except by contiguity; but without this there could be no mental life whatever. To this principle are due, not only the power to form associations between words and their meanings, which constitutes the distinctively human faculty of language, but also such associations as those between the sight

and the taste of food, which guide the voluntary actions of animals.

Forgetting is a case of Loss of Habit by disuse. Reappearance of memories supposed to be lost.—We have seen that habits are liable to be lost by disuse. This is universally true, and it is perhaps more conspicuously true of mental habits than of any other kind. Memory, as we have seen, is altogether due to mental habit, and consists in the liability of impressions to be recalled into consciousness. In virtue of the law of the loss of habits by disuse, any impression which remains for a sufficiently long time without being recalled into consciousness, ultimately loses the power of being so recalled; in common language, it is forgotten. But we have also seen that the tenacity of a habit does not always depend on its prominence, or present strength; and that a tenacious habit may revive after appearing to be lost. To this class of facts belongs the very remarkable yet not uncommon fact of the recollection in illness or in delirium, of long-forgotten memories of childhood.

Consciousness is an Active state.—We have further to observe that in the mental processes treated of in the present Chapter, there is always an element of activity. It is a mistake to think that in consciousness and memory the mind can ever be quite passive. Even when Will is quiescent, and the conscious mind is most nearly passive, it maintains an activity comparable, if not to that of an animal in motion, at least to that of a growing and developing tissue. Consciousness is a state of activity, and total mental inactivity is possible only in unconsciousness.

From Mental Habit, the logical order would be to go on to Mental Intelligence; but there are several subjects which it will be more convenient to consider first.

NOTE.

DR. CARPENTER ON MEMORY AND ASSOCIATION.

Memory and Association referable to the Laws of Habit.—The following extract from Carpenter's *Mental Physiology* (pp. 343, 344) will show that my view of Memory and Association, as depending on the laws of Habit, agrees with his :—"The psychical principles of Association, and the physiological principles of Nutrition, simply express—the former in terms of Mind, the latter in terms of Brain—the universally-admitted fact that any sequence of mental action which has been frequently repeated tends to perpetuate itself; so that we find ourselves automatically prompted to think, feel, or do what we have before been accustomed to think, feel, or do, under like circumstances, without any consciously formed purpose or anticipation of results. For there is no reason to regard the cerebrum (or true brain) as an exception to the general principle, that while each part of the organism tends to form itself in accordance with the mode in which it is habitually exercised, this tendency will be especially strong in the nervous apparatus, in virtue of that incessant regeneration which is the very condition of its functional activity. It scarcely indeed admits of doubt that every state of ideational consciousness [1] which is either very strong or is habitually repeated, leaves an organic impression on the cerebrum, in virtue of which that same state may be reproduced at any future time in response to a suggestion fitted to excite it. And this pyschical response, which is for the cerebrum what a secondarily automatic movement is for the sensori-motor apparatus, no less certainly depends upon a reflex (or automatic) action of the cerebrum, than does a habitual (muscular) movement on the reflex action of the axial (or spinal) cord."

[1] By "ideational consciousness" Dr. Carpenter appears to mean what I call simply consciousness.

CHAPTER XXVI.

MENTAL GROWTH.

In the foregoing Chapter, we have seen that forgetfulness, no less than memory, is a case of the law of Habit. We have now to show how memory and forgetfulness work together in building up what may be called mental tissue.

The organism is constructed out of the food by the organizing power.—Every organism is built up out of the substance of its food. But this is evidently not a full account of the process of nutrition. There must be not only materials, but something that builds with the materials; and this something is the principle of life, or the organizing power.

Mind is constructed out of Impressions of Sense by the Mental Intelligence.—The growth of mind is analogous with this. As all materials come to the organism from without, so the materials of knowledge come to the mind from without, in the shape of impressions on the senses. All knowledge begins with sensation; we have no "innate ideas:" previous to sensation we have neither ideas, nor knowledge, nor any actual mental existence whatever, but only the potentiality of a mental existence. To quote the old scholastic axiom, "There is nothing in the mind but what it has derived from sensation." But this is evidently not a full account of the process of mental growth. There must be not only materials, but something that builds with the materials. As Leibnitz expressed it, we must modify the scholastic axiom, and say: "There is nothing in the mind

but what it has derived from sensation, *except the mind itself.*" From the point of view to which we have now attained, this axiom may be thus amplified:—"There is nothing in the organism but what it has received in the food, except the organizing principle of vital intelligence which builds up the organism; and there is nothing in the mind but what it has received from sensation, except the organizing principle of mental intelligence, which evolves knowledge out of the materials received from sensation."

Assimilation and Waste in the organism are analogous to the receiving and forgetting of mental impressions.—We have not yet, however, fully stated the closeness of the analogy between organic growth and mental growth. The living organism, while it is constantly acquiring and assimilating new material, is as constantly parting with old material. These two processes respectively constitute nutrition and waste; and the excess of nutrition over waste constitutes growth. The process of mental growth is parallel to this. The mind is constantly receiving impressions from the external senses, and as constantly losing the impressions by forgetting them; old impressions on the memory fade away and are lost, and new ones supply their place; and mental growth consists in the excess of what is remembered over what is forgotten: mental growth goes on so long as the new impressions which are retained exceed in number, force, and variety those which are lost. As organic growth consists in the organism acquiring more substance than it parts with, so mental growth consists in the mind acquiring more and stronger impressions than it loses. Waste is most rapid in the early youth of an organism, but at that period nutrition is more rapid still, and consequently bodily growth is most rapid in early youth; and the corresponding law is true of mental growth.

Waste is a condition of Organic life; so is Forgetting of Mental life.—The foregoing is evident when stated; but the parallel

is closer still. Waste, no less than nutrition, is a necessary condition of organic life and growth. The organism is not like a crystal, which simply acquires substance, and, when it has done growing, remains in a state of molecular immobility. Both during growth and after growth has ceased, the organism is constantly losing substance and replacing it with new substance. Every one is aware that this is true of the organism. Every one knows that waste is not an imperfection of the organism, as wearing-out is of machinery, but a necessary condition of life. But it appears to be the general belief, that the corresponding fact in mental life—the liability to lose impressions by forgetting them—is an imperfection and a weakness of mind, as liability to wear and tear is of machinery. It can however be shown that as waste, no less than nutrition, is necessary to the life and growth of the organism, so forgetting, no less than remembering, is necessary to the life and growth of the mind. This may appear a strange paradox, but on consideration it will become evident.

If we remembered everything, we could not think.—If we remembered all the mental impressions that we had ever received since the beginning of our mental life, we should be distracted by their multitude and overwhelmed by their weight. If the sound of every word of our own language, or of any other language with which we have become familiar, were to recall to memory every time we had ever heard it pronounced; or if the sight of every familiar face were to recall every time we had ever seen it; if all details, the most insignificant as well as the most important, the least interesting as well as the most interesting, were to come crowding unbidden into memory whenever we desired to think of any object or of any event, —the mind would, as it were, have no room to move, and thought would be impossible. But such a result is prevented by that constitution of the memory in virtue of which we retain, generally and on the average, the important and interesting particulars of any object or of any event, and forget the rest; s

that, on the whole, we retain what we need to retain, and forget what we do best to forget.

Coalescence of residua by forgetting. Process of learning our own language.—Further, the greater part of our mental acquisitions does not consist of mental pictures of single objects, or mental representations of particular events. Such pictures and such representations are not formed until memory develops into the power of recollection, and it is not probable that animals or young children form them at all. The rapid mental growth of young children consists in acquiring, not the residua of single impressions, but the coalesced residua of many impressions. An impression leaves its residuum in the memory; and when it is often repeated, the residua of the several impressions become inseparable and indistinguishable, and coalesce into one. It is in this way that we become familiar with the words of our own language, and with everything else that is familiar; indeed, it belongs to the definition of familiarity, that we are not familiar with anything until we have forgotten how often we have witnessed it. The earliest, the most durable, and the most important of our mental acquisitions are of this kind. The best instance of this is, perhaps, our knowledge of our own language. We have become familiar with words in common use, not by hearing them once, but by hearing them oftener than we can remember; our knowledge of any common word is not a single residuum from the impression made by hearing it once, but a coalesced residuum, consisting of the indistinguishably united residua that have been left at each time we have heard it.

Words must not only suggest their meaning; they must suggest nothing else. The first of these is secured by remembering, the second by forgetting.—In order that language should rightly fulfil its function of communicating thought, it is necessary that every word shall suggest its meaning; but more than this is needed; it is further necessary that every word shall suggest nothing else. The requisite that a word shall suggest its

meaning is secured by the power of memory: the requisite that it shall suggest nothing else is secured by the not less necessary, though purely negative, power of forgetting. The sound of a word may have been heard a thousand times, under circumstances which were never exactly alike; the speaker, the words before it in the sentence, the words after it, and all other circumstances, have been constantly varied, excepting only the only important circumstance, namely its meaning; which is also the point most attended to. In virtue of the law that strong or often-repeated impressions on the consciousness leave residua in the memory, the word itself and its meaning are remembered; in virtue of the law that feeble or seldom-repeated impressions on the consciousness fade altogether away, the varying and unimportant circumstances under which the word has been heard are forgotten. Of all the complex impressions which have been produced on the mind by the word, as it has been heard a thousand times under as many partly dissimilar circumstances, the varying and unlike elements are forgotten, while the constant elements—that is to say, the sound of the word and its meaning—are retained; and the residua of the thousand impressions, having become alike by the loss of their unlike elements, are indistinguishable, and coalesce into one. By this process, the word comes to remain in the memory, separate, detached, suggesting its meaning, and suggesting nothing else. But if the residua of all the thousand impressions did not lose their unlike elements, they would still be distinguishable, and could not coalesce into one. The word would indeed remain in the memory, but not as a single coalesced residuum; it would not be separate and detached from irrelevant objects: it would no doubt suggest its meaning, but it would suggest so much else that it would not serve the purpose which language is meant to serve.

Formation of Habits of Action by the same law.—The knowledge of a language does not however exclusively consist in associations between the sound and the meaning of the words;—it

includes also those motor habits—namely, the habitual power of using the organs of voice—which are needed for speaking it. This brings us to the subject of the formation of habits of action; and in the process whereby these are formed we find the same law of forgetting and necessity of forgetting. "We learn to do a thing by doing it." Mechanical arts, however, are a better instance of this than the power of speech. The process of learning a mechanical art is this: that actions are at first performed voluntarily and with conscious attention; but, in virtue of the law of habit, the oftener they are repeated the easier they become, until at last, in many cases, they cease to need any co-operation of the will or of the conscious attention. They have no doubt to be voluntarily set going, but when set going they are continued automatically; the stimulus and guide to each successive action of the muscles being sometimes the action next before it, sometimes the sight of the work or the instrument before the workman. Some musicians become able to perform in this way, the stimulus of sense being given either by the sound of the successive notes, or by the sight of the printed music. What I wish to point out is the perfect similarity between this process and the process by which we learn our own language; or, in more general terms, between the process of acquiring motor habits and the process of acquiring purely mental associations. We have seen that, in order to have the association between words and their meanings in an available form in the mind, the residua of all the impressions received from hearing any word must coalesce in the mind into a practically single residuum; and this is done by forgetting the merely accidental circumstances under which we have heard each word. Just so in learning an art. Before it can be performed automatically, the memory of each separate time that it has been practised must be lost, and the residua of them all must coalesce into one, which single residuum constitutes the acquired habitual power.

Moral benefit of forgetting.—The necessity of forgetting is good

for us in another way. Our life and our duties are in the present, and it would be bad for us were our thoughts to be too much in the past; but this is for the most part forbidden by the law of the certain though slow and gradual fading away of all impressions which are not renewed. It is in virtue of this law that time mitigates grief, even when no nobler influence is at work.

> "We forget because we must,
> And not because we will."[1]

[1] Matthew Arnold.

CHAPTER XXVII.

TIME, SPACE, AND CAUSATION, REGARDED AS FORMS OF THOUGHT.

Probable judgment of History on the now dominant Philosophy.—When the time is come for regarding the philosophy of the present age from the same historical distance at which we look back on the controversies before the time of Kant, the decision will probably be something like this:—

"The English philosophers of the nineteenth century were the first to place mental science on its true physiological foundation. It had long before been laid down as an axiom, that 'there is nothing in the mind except what it has received through sense;' to which Leibnitz added, 'except the mind itself;'—and Kant had shown as a fact, independent of any theory, that such conceptions as those of Time, Space, and Causation, belong to the structure of the mind, being forms of thought (or rather of intuition); moulds, as it were, wherein the material furnished by sensation is cast into form. But to Herbert Spencer, before all, belongs the honour of showing the importance in psychology of inherited experience, and thus leading the way to the explanation of those conceptions; which are now universally regarded as results of the experience of the race which have become forms of thought for the individual.

"But their treatment of these questions was incomplete. They made the great mistake of explaining Causation as

having no other meaning than unconditional Sequence. This was probably due to their tendency to overrate the importance, as a source of knowledge, of external Observation in comparison with Consciousness; we cannot otherwise understand how they could fail to see the truth which is so evident to us, that Causation means Force, and becomes known by the mind's consciousness of its own activity. This appears to be also connected with the almost exclusive attention which they paid to the conception of Space, to the neglect of that of Time; for Space is conceived as external to the consciousness, in a way that Time and Causation are not. While they did very much to clear up the mystery of the relation of the mind to Space, they seemed comparatively unconscious of the far deeper and more fundamental mystery of its relation to Time, and the question therewith involved of the nature of personal identity.

"It is however remarkable that this was seen by John Stuart Mill, who, though his influence on subsequent thought has been much less than that of Darwin or Spencer, was the most representative thinker of his own time. Let any one who can recognise similarity of thought through diversity of expression, compare the chapter entitled 'The Psychological Theory of the Belief in Matter, how far applicable to Mind,' in Mill's *Examination of Sir William Hamilton's Philosophy*, with the 'Dissertation on Personal Identity' appended to Butler's *Analogy of Religion*, and he will see that Mill, belonging to a different period from Butler and to an opposite school, and resembling him in nothing but an intellectual foundation of hard common sense, arrived nevertheless at what is essentially Butler's conclusion:—namely, that the consciousness of personal identity through time and change is an ultimate fact. The only difference between them is that Butler states, without hesitation, and as his own conclusion, what Mill states as a somewhat hesitating concession, as if to an opponent."

We now go on to discuss these subjects from our own point of view.

Personality and Individuality.—The word *self* or *I* is used in two different though closely related senses, or perhaps rather in the same sense but in two different contexts. Used in one way, it means the permanent element in consciousness—the permanent self, as opposed to the changing succession of feelings, thoughts, and volitions. Used in the other way, it means self as opposed to the external world. It will be convenient to have distinct names for these two conceptions. Let us call the permanent element in consciousness Personality, and the distinction of self from the not-self, or the external world, Individuality.

Relation of Personality to Time.—The consciousness of Personality and the conception of Time come into existence together. It is generally admitted that all consciousness is primarily consciousness of difference, and difference expressed in time is change. Consciousness is first awakened by the commencement, the cessation, or the change, of a sensation;—were the same sensation continued for ever, there is every reason to believe that it would not produce consciousness. In the same act of consciousness we become conscious at once of change, and of personal identity through the change. Changing sensations and the permanent self are thus correlatives in consciousness, and we could not be conscious of either alone. Further, in the same primary act of consciousness we become aware of Time, wherein both the changing and the permanent elements of this cognition exist. Thus the consciousness of Personality involves three terms: namely, changing feelings, personal identity through the change, and Time, which, as a necessary condition, underlies both change and permanence. The sense of identity through change includes belief in the reality of the past, or, what means the same, in the veracity of memory, which tells of the past.

Memory is essential to Consciousness.—These facts of consciousness are primary. It is implied in this analysis, that at least a rudimentary memory is an essential factor in consciousness.

Parallel relation of Individuality to Space.—Individuality is related to Space, nearly in the same way that Personality is related to Time. All consciousness is primarily consciousness of difference, and we become conscious of our Individuality in the same act whereby we become conscious of the existence of a world external to it. In other words, self and not-self are correlatives, and neither conception can arise without the other. Further, the external world is, as a matter of fact, found to exist in space. Parallel to the three terms involved in the consciousness of Personality, there are thus three terms involved in the consciousness of Individuality, namely the External World or Not-self, Self as distinguished therefrom, and Space wherein both exist. Perception, or the faculty whereby we learn at once to know the external world and the self which perceives it, is related to Individuality, as Memory to Personality; and as the sense of Personality involves belief in the veracity of Memory, so does the sense of Individuality involve belief in the trustworthiness of Perception.

Tabular statement of the Parallelism.—It is worth while to state the parallelism in tabular form.

Personality	Individuality
involves two terms, namely	*involves two terms, namely*
Changing Sensations	The External World
and	*and*
The Permanent Self,	Self, or the Ego,
besides	*besides*
Time,	Space,
which underlies the other two. The correlative knowledge of the changing and the permanent elements depends on	*wherein both exist. The correlative knowledge of the external world and of self depends on*
Memory	Perception
and	*and*
the belief in the veracity of Memory.	the belief in the trustworthiness of Perception.

Memory is primary in Consciousness, Perception is secondary.—But, notwithstanding the closeness of this parallelism, the two developments do not take place together. Memory, with the sense of Personality and Time, is primary; while Perception,

with the sense of the external world and Space, is secondary. Memory and the sense of Time enter into all consciousness; not only into all human consciousness, but into all consciousness of which it is possible for us to conceive. The same is not true of Space. Although, as a matter of fact, the idea of the external world is developed in inseparable connexion with that of Space, this does not appear to be the result of any logical necessity; on the contrary, it appears to be only a result of the constitution of our perceptive faculties, whereby the knowledge of the external world is given almost exclusively by the senses of Touch and Sight, which in the same act give knowledge of Space.

Relation of Sight and Hearing to the Intellect.—Time becomes known as the abstract of all successions, but it is a mistake to say that Space becomes known as the abstract of all co-existences. If we had no sense except that of sight, we could not be conscious of two co-existent sensations without perceiving them as separated in space, because when two or more elementary sensations of sight—that is to say two or more colours—occur at the same time and place, they combine into one sensation; the three primaries combine into white, but white appears to be, and therefore is, a single sensation; no eye, however accurate its discrimination, can see the primaries in white. But with the sense of hearing it is different; it is possible to perceive simultaneous sounds as distinct; and this is a case where co-existence is perceived without reference to Space. It is true that the ear has some slight power of distinguishing direction, but this would be insufficient to give any idea of Space if it were not otherwise acquired. If, consequently, our intellect were developed from the sense of hearing alone, we should have a consciousness of Time, and of sensations co-existing in Time, without referring the co-existence to Space.

Is the cognition of Space primary? Opposite opinions.—Is then the relation of the mind to Space fundamentally different

from its relation to Time? I think not. No one disputes that our knowledge of Time is immediate and primary; that we cognize Time in the same act wherein we cognize the succession of our own feelings or thoughts in Time. But there is great difference of opinion respecting our cognition of Space. The prevailing theory among the Germans of the present generation is that the cognition of Space is equally primary with that of Time; that as we cognize Time by the succession of sensations in Time, so we cognize Space by the separation of sensations in Space; for instance, by the sensations of different colours in different parts of the retina, or by holding one hand to the fire while the other remains cold. The prevailing theory among the English appears, on the contrary, to be that the knowledge of Space is obtained solely by moving in it; and as all motion takes place in time, they infer that our knowledge of Space is not a primary cognition, but is derived from that of Time, through the muscular sense, which gives consciousness of motion.

I maintain the affirmative.—On this question I agree with the Germans. I think that the cognition of Space is primary and underived.

Similarity of Space and Time.—In approaching the question whether our knowledge of Space is really a primary cognition like that of Time, we first meet with this fact, that whether Time and Space are considered in themselves or as objects of thought, they are in many important respects like each other and unlike anything else. Considered in themselves, they are both infinitely extended, and both infinitely divisible. Magnitude is expressible in terms either of time or of space. Both have reality, though neither has existence; all things exist in Space, and all events occur in Time. Considered as objects of thought, they are both necessary; that is to say, we cannot conceive them as not being. We can voluntarily form a mental conception of the absence of all existing things, but Space will

remain: we can similarly conceive the absence of all events, but Time will remain. We cannot conceive, by any effort of the mind, of a limit to either: we cannot conceive of a boundary in any direction to Space, nor can we conceive of a beginning or an end to Time.

The idea of Space cannot be derived from that of Time.—If however it can be shown that the idea of Space can be derived from that of Time through motion, the conclusion ought to be that it is so derived. But I maintain that this is impossible, because no possible modification of the idea of Time will get more than one dimension out of it. Time will give the ideas of distance, and of reverse direction; but no ingenuity will cause it to give the idea of more than one dimension, or of angular magnitude. This is simple and commonplace, but it appears conclusive. Professor Bain's doctrine, that Space becomes known to us exclusively through the experience of motion, is a tenable opinion, though I have shown that I do not agree with it; but his inference from this, that Space *is* the idea of unresisted motion and has no other meaning, appears not only metaphysically but logically absurd. It seems to assert that Space is created by our experience of Space; in opposition to the logical and metaphysical certainty that the experience of Space implies its existence before the experience of it could arise.

Time is more inseparable from our thoughts than Space.—So far as I see, the only reason for thinking that the cognition of Space is less primary than that of time, is the fact, of which every one must be aware who has read or thought on the questions of modern metaphysical controversy, that there is something perplexing, something, it may be said, unmanageable, in the relation of the mind to Space, which there is not in its relation to Time. And, argue as we may, we cannot get rid of the fact, that Time is much more inseparable from our thoughts than Space. It is true, as already remarked, that we cannot conceive of a universe

without them both. But it is also true that we think in Time, and do not think in Space; and we cannot by any process of reasoning get rid of the notion that Space is external to the mind, in a sense which is not true of Time.

Reasons of this fact.—This fact however can be explained in a way which does not prove the idea of Space to be a derived one. We have seen already that Memory and the idea of Time are primary in consciousness and essential to its existence, while Perception and the idea of Space are only secondary; and moreover, the perceptive faculties of Man have characters which greatly complicate the theory of the relation of Man's consciousness to Space.

The intellectual senses, Hearing, Sight, and Touch.—Man has several senses; but the only senses which have to be considered at present are Hearing, Sight, and Touch (including in Touch the muscular sense), for these are the only senses which in Man have any appreciable effect in producing mental development. It is through Sight and Touch exclusively that the idea of Space is given; and Hearing, which alone among the three intellectual senses gives no idea of Space, is of all the senses the most closely associated with thought. This is a consequence of the habit of thinking in words, which is necessary to any high development of thought. Speech, which is not only the notation but the instrument of thought, is addressed to the sense of Hearing; and there is no similar faculty connecting thought with any other sense.

Moreover, two impressions on different senses, as when we see a flash and hear a shot, are cognized as being either simultaneous or successive in Time; while only sensations of the same sense either of Sight or of Touch, are primarily cognized as related to each other in Space. I say primarily, because we have every reason to believe that the power of identifying a visual object with a tangible one is an acquired power. If we had never seen anything that we had felt, and had never felt anything that we

had seen, the idea of identifying the objects of Sight and of Touch would not occur to us as possible or conceivable.

There is thus quite enough in the constitution of the sensory faculties of Man to account for the fact that we think in Time and not in Space, and that Time is inseparable from the human consciousness, while Space can only be thought of as something external to it. There is enough, I say, in the constitution of our sensory faculties to account for these facts, without the aid of any such hypothesis as that of the conception of Space being derived from the conception of Time by means of the experience of motion.

Case of a Consciousness developed from Sight alone.—But these, though facts of the human consciousness, are not necessarily true of all consciousness. Were an intellect like ours to be developed, as it might conceivably be, out of the sense of Sight alone, though Memory and the consciousness of Time, even in such a case, would be primary, and Perception and the consciousness of Space only secondary; yet Space would probably seem as close as Time to its consciousness when developed, and it would think not only in Time but in Space;—not by means of speech as we do, but by means of writing, or diagrams made or imagined in Space.

Share of the muscular sense in giving knowledge of Space.—It is not denied that our conception of Space is partly due to our experience of motion. The most probable suggestion appears to be that touch and sight, without motion, give the idea of superficial extension, and that the idea of a third dimension is given by our own muscular motions.

Necessary Truth: Logical and Arithmetical Laws.—The nature and ground of our belief in the necessity of geometrical truth has been much controverted, and the abstractions of logic, algebra, and arithmetic appear to be a better ground than those of geometry whereon to discuss the meaning of universality

and necessity as applied to intuitions. We believe, without needing verification of any kind, that logical principles, such as the law that a contradiction cannot be true, apply to all possible worlds; and our belief in arithmetical principles is of the same kind. Our conviction of the truth of arithmetical propositions for all numbers whatever is absolute, and has a right to be so;—while if our knowledge of them were based on experience, and our belief in their truth on Habit, we could not be certain that they were absolutely true beyond the limits of experience, that is to say of numbers too large to admit of verification by counting. We believe that the laws of number are true of all magnitudes and in all worlds; while, on the contrary, we have no means of knowing whether there may not be worlds where the laws of motion and of gravitation differ from ours;—where action and reaction are unequal; where the proportion of weight to mass differs in different chemical elements, and its force varies according to some other law than that of the inverse square. This belief in the absolute unchangeableness of the laws of number appears to be due to mental Intelligence, not resolvable into Habit. It has been suggested that if the laws of nature in any world were such, that when two pairs of objects were presented, a fifth object was always presented with them, in such a world two and two would make five;[1] but this would really not be $2 + 2 = 5$, but $2 + 2 + 1 = 5$, just as we know it.

Geometrical Laws.—There is thus a sharp contrast between our intuitions of logical and arithmetical truth on the one hand, and our experimental knowledge of physical facts on the other. Geometrical intuitions appear to be of a character intermediate between these. It is not credible that the properties of Space should, at some enormous distance, be different from those of which we have experience; but it seems to me credible, though to our faculties not conceivable, that the number of dimensions in Space may be infinite, though we exist and move in only

[1] See *Essays by a Barrister.*

three dimensions. We can imagine beings with infinitely thin bodies, existing and moving in space of only two dimensions; and if their mental constitution were similar to ours, they would be as unable to conceive of a third dimension as we are of a fourth.

Case of a being having experience of Space through Sight only.—Moreover, an intelligent being deriving its knowledge of Space from the sense of Sight alone would have no idea of a third dimension, because the eye sees surface only. And further;—the superficial extension thus cognized would not be that of a plane surface, but that of the interior surface of a sphere; for the eye sees all things, as it sees the stars, projected on a sphere. It is geometrically impossible for a plane surface or a straight line to become an object of Sight. Plane surfaces are seen as portions of the surface of a sphere; straight lines are seen as arcs of great circles on the sphere. When we perceive straight lines and plane surfaces by sight, we do not see them;—we infer them from what we see. The only geometrical knowledge possible to such a being would be the geometry of figures drawn on a sphere; and a race of such beings would perhaps make the first great improvement in their geometrical methods, by introducing the conception of infinitely small portions of surface whereon to study the properties of figures. On such infinitely small surfaces, though not on surfaces of finite magnitude, they would find the geometry which we know as that of Euclid to be true. And perhaps they would find themselves compelled to postulate the existence of a third dimension, as a hypothesis incapable of direct verification, but needed in order to make geometrical facts intelligible.

A Barrister's Puzzle.—The foregoing remarks have been suggested by Reid's *Geometry of Visibles,* and they will show what to think of the following puzzle from *Essays by a Barrister*:—

"It would be possible to put the case of a world in which two straight lines would be universally supposed to include

a space. Imagine a man who never had any experience of straight lines through the medium of any sense whatever, suddenly placed upon a railway stretching out on a perfectly straight line to an indefinite distance in each direction. He would see the rails, which would be the first straight lines he had ever seen, apparently meeting, or at least tending to meet, at each horizon; and he would thus infer, in the absence of all other experience, that they actually did inclose a space when produced far enough."

We reply to this that he would see, not two straight lines but arcs of two great circles, each being nearly a semicircle; and, so far as given in the problem, he would have no reason to infer anything else.

Such cases do not prove Geometrical Intuitions to be doubtful.—Were such cases as these to be real, they would not have the slightest tendency to prove our geometrical intuitions untrue or doubtful. Such experiences and intuitions of Space as we have supposed, are perfectly true, though more limited than ours; and if it is true that there are four, or an infinite number, of dimensions in space, this does not prevent our geometry of two and three dimensions from being perfectly and absolutely true, within its limits.

Knowledge of Causation from consciousness of mental activity.—We have now to consider the origin and meaning of the idea of Causation.

It seems to me that this idea is originally derived from the mind's consciousness of its own activity. If we examine our conceptions only by the light of external observation, we shall find nothing in Causation but "unconditional antecedence," and nothing in Substance but permanence. It is not theory but mere fact—perhaps we may say mere definition—that causes are unconditional antecedents, and that the external world becomes known to us as consisting of "permanent possibilities of sensation." But these statements are not exhaustive. If we examine

our ideas by the light not only of external observation but also of internal consciousness, we shall see ourselves forced to recognize that *where there is action there must be an agent.* This, it seems to me, is the fundamental axiom of metaphysics, and is the justification of our ordinary spontaneous belief respecting both Causation and Substance.

Substance identified with Agency.—A Substance really means an Agent, because Existence is known only through Action; using the words Action and Agency in their widest possible sense, so as to include, in mind, not only will and thought but the faculties of sensation, and in the world of matter, not only force but inertia. It is only a particular case of this truth, that matter can no more be conceived apart from force, than force apart from matter.

Causation is related to the mind's activity as Time to its passivity.—Causation is related to the mind's activity as Time to the mind's receptivity. Consciousness is never really passive, for it is essentially an active state; but we speak of its receptivity to denote mere sensation and memory without thought or will. A purely receptive state of mind would be sufficient to produce the idea of Time, but it could give no suggestion of Causation. The idea of Causation—not in the sense of invariable antecedence, but of *efficiency* or *force*—enters with thought and will. When we hear sound reasoning and it causes conviction, or when we hear good or bad news and it causes joy or sorrow, we become conscious of the relation of Causation between two mental facts. We also become conscious of the same relation in another form when we direct thought by a conscious determination of the will. Thus Causation, like Time, is known by immediate consciousness; we are directly cognizant of one state of consciousness as the cause of another.

Action of the will on the muscles.—It must be understood that this analysis does not apply to the will as the cause of

muscular action; for between the determination of will whereof we are conscious, and the muscular action whereof we are also conscious, there is at least one link of nervous action whereof we are unconscious.

Through muscular action we extend the idea of Causation to the external world.—Nevertheless, it is through muscular action that we learn to extend the idea of cause, in the sense of force or efficiency, from mental action of which we are directly conscious, to physical action of which we are not directly conscious. We spontaneously believe that fire causes heat in the same sense as that in which we know that good news causes joy; and the connecting link by which we learn to identify Causation as cognized within the mind with Causation as inferred in the world of matter outside of it, consists in the fact that we have the power, inexplicable as that power is, of making our own will an acting cause in the world of matter. Thus, if I will to think, my thoughts act as desired; if I will to write, my fingers and my pen act as desired; and though the causal connexion is within the sphere of consciousness in the one case and not in the other, yet the effect follows the cause in both cases with equal certainty, and we learn to identify the nature of the causal action in the two cases. In other words, we identify the two facts of mental Causation and physical Causation in consequence of the fact that a mental determination is capable of becoming a physical cause; as when the determination of my will causes the motion of my pen.

Knowledge of Causation is due to internal experience.—It will be seen that in this account of our original cognition of the relation of cause and effect, I ascribe it to experience, although I differ from Mill and the rest of those who regard causation as nothing more than "uniform and unconditional sequence." I agree with them in ascribing it to experience; but they ascribe it to experience of the facts of the external world which we observe; I ascribe it to experience of the facts of the mind, of

which we are directly cognizant. When we say, for instance, that "fire is the cause of heat," we state a fact which we have learned purely from external observation. But Mill maintains that when we say that "fire is the cause of heat," our only meaning is that "fire always emits heat, and nothing more than the fire itself is needed in order to have heat." I think, on the contrary, that more is meant than this. We apply the analogy of our own mental experience to the external world, and infer that fire causes heat in the same sense in which good news causes joy, or evidence causes belief. It may be said this analogy is plausible only to that intellectual state in which men try to explain the facts of the external world by the fancies of their own minds. I reply that the rejection of this analogy belongs to that exploded system of psychology in which mind and matter were regarded as distinct and totally unlike substances. The progress of science has gradually brought us back to the spontaneous conclusion of the earliest conscious thought in pre-metaphysical ages; namely, that the mind of man is not distinct from the material world in the midst of which it is placed, but is the highest product of the forces of that world.

Summary.—To sum up in the fewest possible words the results at which we have arrived:—Time, Space, and Causation are facts of the universe which have become forms of thought in consequence of coming within the sphere of our consciousness. Our ideas of Time, Space, and Causation are results of the experience of the race which have become forms of thought for the individual.

The belief in the past infinity of Time is not due to experience. —But this does not exhaust the question. Any account of our conceptions of Time and Space, if complete, ought to explain why we believe in the infinity of both. Those who regard these conceptions as mere results of experience, say that we have never found any limit to Space, and are therefore unable to conceive of any; and that we have never found an end of time,

and are therefore unable to conceive of any. I cannot, however, think this satisfactory. We believe that Time is alike without end and without beginning; and any theory of the subject ought to account for this twofold belief. Now the pure and simple experience-theory does not account for this. It accounts for the belief that time is without an end, by the fact that we have never had experience of any portion of time without another portion of time coming after it. But this will not apply to our belief that time is without a beginning; for the first time that any one's consciousness was awakened, he had at that moment experience of a portion of time without having experience of any other portion of time coming before it; so that, for anything that mere experience can witness to, there is nothing inconceivable in a beginning of time.[1] This shows that, although we obtain our first knowledge of Time by direct cognition, and it has become a form of our thought by hereditary Habit, yet there is something in our knowledge of its properties for which mere habit will not account, and which can be referred only to that mental Intelligence which is not a result of Habit. If this is true of the conception of Time, it is no doubt equally true of the conceptions of Space and of Causation.

The Question of the Reality of our Knowledge.—But if it is true that we have acquired the ideas of Time, Space, and Causation by experience, does it not follow that there are realities external to the mind, corresponding to those ideas? The philosophy which bases itself on experience has in our days run strangely into idealism, but it ought to be, and I trust will yet show itself to be, the philosophy of common sense. Not that it is to be superficial; very far from this; but a true philosophy ought to explain, and, in explaining, to justify, the natural, universal, and instinctive beliefs of mankind; and it seems to me that in denying the external objective reality of Time, Space, and Causation, the philosophers of experience

[1] This difference has been pointed out to me in conversation by my friend Archdeacon Reichel.

are false to their own principles. Neither the individual nor the race could have the experience whereby these ideas have been originated, if the realities corresponding to these ideas had not existed before our experience of them began. Space, Time, and Causation are not the result but the cause of our experience of them. Our minds have not created, but have discovered them.

Escape from Metaphysics.—If this is true, we have escaped from the cloudland of metaphysics, not by retreat, but by going on till we have come out at the farther side, into common sense and inductive science, yet without losing anything that we have really gained in our wanderings through that cloudland; and we stand again, as we stood in our unmetaphysical childhood, on the firm familiar earth and in the "light of common day," trusting with not only an instinctive but a rational trust, that our knowledge, having grown from experience, truly interprets experience;—that the framework of our thoughts, being produced by the constant action of the external world on our bodily and mental organisms through countless generations, really corresponds to and represents the realities of the external world.

CHAPTER XXVIII.

THE GROUNDS OF THE MORAL NATURE.

The Root of the Moral Nature is in the Sense of Pleasure and Pain.—The intellectual nature begins from sensation, and the first rudiment of intellect consists in the power of cognizing the relations between different sensations. It is no less true that the moral nature begins from sensation. The first rudiment of the moral nature consists in cognizing the difference between agreeable and disagreeable sensations, and in desiring the one and disliking the other.

Pleasure and Pain are Guides to Sentient Organisms.—Pleasure and pain—the agreeable and disagreeable qualities of sensations —cannot be resolved into anything simpler than themselves; but it may be possible to explain when and how they arise. We have stated,[1] as the general law of vital Intelligence, that it directs all the actions of the organism, whether formative or motor, in whatever direction is best for its life and health. When a mental nature is developed, the same becomes true of mental Intelligence.

All organisms are intelligent, but only some are sentient. All organisms, as a general law, seek what is good for them and avoid what would be injurious. Insentient organisms are guided in doing so by their unconscious Intelligence; and when sensation is developed, with the power of discriminating between pleasure and pain, the sense of pleasure and

[1] See p. 414.

pain becomes a guide; what is beneficial is sought as being agreeable, and what is injurious is avoided as being disagreeable. Sensation does not supersede Intelligence, but guides it.

Exceptions. The General Law is maintained by Natural Selection.—The law that beneficial things are felt as agreeable and injurious things as disagreeable, is subject to very perplexing exceptions; such as the sweet taste of some poisonous substances; and, what is much more wonderful, the propensity of winged insects to rush into the flame of a candle. But these are only exceptions;—the general law which identifies health with enjoyment, and the converse, is maintained in force, if in no other way, at least by natural selection, which will inevitably destroy any race that may acquire the habit of taking pleasure in injurious things.

Desire and Fear. Love of Life.—Out of the sense of actually felt pleasure and pain arise the desire of pleasure and the fear of pain; so that, when organisms acquire desires and fears, the law of pleasure and pain stated above causes them to desire what is favourable to their life and health, and to fear what is injurious. This is the ground of the love of life and the fear of death. These feelings would be scarcely explicable if they had their roots in thought, or even in sensation; but their roots are deeper than either thought or sensation, down in the nature that we have in common with all organisms whatever, vegetable as well as animal, which prompts all alike to seek whatever ministers to their life. In other words, the impulse to self-preservation is universal among organisms, sentient and insentient, conscious and unconscious. We have become conscious, and the impulse to self-preservation has become conscious in us, and is called the love of life, or the fear of death.

The Sexual, Domestic, and Social Affections have their Roots in the Organic Life.—Organisms are guided by organic Intelligence

to perform not only such actions as are salutary for the individual, but also such as are needed for the perpetuation and the prosperity of the race. The simplest and the only universal instance of this is the reproductive function. When organisms become sentient and conscious, the actions which minister to the life of the race, as well as those which minister to the life of the individual, are attended with a sense of pleasure and become objects of desire. These feelings constitute the root of the sexual, domestic, and social affections. Thus the instinct of a bird, for instance, causes her to tend her young: she probably has a sense of pleasure in doing so; and, if she loses them, she shows signs of mental pain. This is an instance of the general fact that the healthful performance of every vital function, in so far as it is attended with sensation or consciousness, gives rise to a sense of pleasure, and any interference with its performance gives rise to a sense of pain. The affection of a bird or other animal for her young thus has its root deeper than consciousness or sensation, in the instinctive Intelligence which prompts all organisms, conscious and unconscious, animal and vegetable alike, to minister to the life of the race as well as to their own; and the same is true of the attachment, outlasting mere desire,[1] which some animals feel for their mates. The pleasures and pains, the hopes and fears of sympathy, all the unselfish emotions, and all that makes of man a social being, grow out of this root. So far as I see, the origin and nature of the sympathetic and social character of Man neither need nor admit of any other explanation than that which is here suggested.

[1] "Die Leidenschaft flieht,
Die Liebe muss bleiben:
Die Blume verblüht,
Die Frucht muss treiben."—SCHILLER.

"Summer her bloom must shed,
Ere Autumn's fruit can swell;—
And Passion in many a heart is dead,
Where Love remains to dwell."

Great Changes are injurious, slight ones beneficial: Great Changes are painful, slight ones agreeable.—In speaking of the laws of habit, another way was suggested in which the sense of pleasure and pain is to be directly referred to the elementary laws of life. We saw that great changes of the circumstances in which any organism has to live are injurious and destructive, while slight changes are beneficial.[1] It is also a general law, that when organisms become sentient, what is beneficial is felt as agreeable, and what is injurious is felt as painful. From these two laws, it follows by mere syllogistic inference that great changes are felt as painful, but slight changes are felt as agreeable; and this is affirmed by all experience as a general fact of our mental nature. We like familiar things and familiar ways, and yet we weary of monotony and like novelty. This sounds contradictory, yet we know that it is true. The full statement of the truth, divested of its paradoxical form, is that we like what is familiar, but we like it to be diversified with slight novelty. It does not in the least degree interfere with the truth of this statement as a law, or rather a pair of laws, of the mind, that the love of familiar things is relatively strong in some persons, and the love of novelty in others; and also that the same persons love novelty in some things, while in other things they cannot endure it. Many persons, for instance, enjoy novelty in such matters as dress and music, to whom the pain of reconsidering a religious or political opinion would be unbearable.

We should commence an inexhaustible subject if we were to endeavour to trace all the applications of this law, that slight novelty is pleasing, but great novelty disagreeable; I shall here only speak of its importance as entering into the constitution of the sense of beauty.

Application of this principle to Beauty.—The sense of beauty is a very complex fact, and I believe that no definition of beauty has yet been proposed which really answers the purpose of a

[1] See p. 106.

definition by including all that it is meant to include, and excluding all that it is meant to exclude. For the present purpose let us narrow the subject as much as possible by excluding moral beauty, such as that of an amiable character, and intellectual beauty, such as that of the theories of gravitation and heat; so that we shall have to do with the beauty of sight and of sound alone. And let us also exclude all elements that properly belong, not to the beautiful, but to the sublime and the picturesque, which, though they are constantly mingled with beauty, are perhaps radically distinct. Having thus narrowed the subject, we shall find that it is tolerably manageable for the purpose of analysis. I do not say that the complex fact of the sense of beauty is capable of being referred to any single principle of our nature. But I say that one element of beauty, and that of great importance, is directly traceable to the law already stated, that slight changes are agreeable, but great changes are painful. Great changes or abrupt transitions are disagreeable to the eye. Violent contrasts of light and shade, or of colour, are not beautiful, or at least are less beautiful than gradation. The same is true of form: a mixture of Greek and Gothic details, for instance, would be condemned by those who are best qualified to appreciate the beauty of either alone. Slight changes and gradual transitions, on the contrary, are demanded by the eye. A vast expanse of a single colour, or the endless repetition of a single form, may be beautiful, but its beauty will be of a low order: a much higher kind of beauty is due to variety of colour where the masses are not too large, as in the case of flowers among foliage; and the highest of all beauty of colour is that which is due to the almost imperceptibly graduated combinations of tint in sunset skies. The soundness of these principles is generally admitted. An artistic design in which they are observed cannot fail to have many of the elements of beauty, though it may be commonplace and unmeaning; while a design in which they are violated can scarcely be beautiful at all.

Roots of Emotions in the Organic Life.—We have now endeavoured to give an account of the origin of some of those feelings which are independently generated in consciousness, and transcend mere sensation. We have successively considered the love of life, the sympathetic and social feelings, and so much of the sense of beauty as consists in the love of gradual variety, or variety in unity; and we have endeavoured to trace them directly to their roots in the nature which we have in common with all living beings, whether sentient or insentient. Their origin does not appear to be in any way traceable to the laws of the association of ideas; though no doubt the laws of association have much to do with their development, as indeed they have with every mental process whatever.

Germ of the Moral Nature in Sensation. Prudence, Unselfishness, and Holiness.—The sense of pleasure and of pain, with the desire of pleasure and the fear of pain, constitute the germ out of which the whole of our moral and emotional nature is developed. But though they are emotional, these elements cannot be themselves regarded as moral. There are three things in which morality or moral excellence consists. These are:—

Preferring the future to the present; or prudence.

Preferring the interest of another to one's own; the social virtues, or unselfishness.

Preferring a higher aim to a lower one; as, for instance, preferring the performance of a duty, which is certain to be unrewarded, to pleasure; I cannot think of any word that properly distinguishes this class of virtues from the other two, except holiness.

Origin of these.—In morality, as in all life, the higher is developed out of the lower, and presupposes the lower. Prudence, unselfishness, and holiness are all developed out of the preference of pleasure to pain. Out of the sense of pleasure and pain in the present arises prudence, or care to provide for pleasure and against pain in the future; and the readiness to

forego a smaller present pleasure, or to endure a smaller present pain, in order to provide for greater future pleasure, or against greater future pain. Out of the sense of one's own pleasure and pain arises unselfishness, or care for the welfare of others. And out of the pleasures and pains, the desires and fears, of mere sensation, arise those feelings which belong to a higher order than sensation—love of beauty, love of truth, and love of virtue.

Concerning the origin of prudence, there is no room for doubt; it necessarily arises when thought and will have obtained the ascendency over mere sensation and consensual action.

The origin of the unselfish virtues is a subject which has been very much debated. I have stated my reasons for believing that they have their roots in those instincts which prompt all organisms, sentient and insentient alike, to perform such actions as are needful for the preservation of the race.

But how have we acquired the idea of holiness? How have we learned that some pleasures, quite irrespectively of their intensity, are higher than others, and worthier to be sought—that the pleasure of hearing music, for instance, is higher than that of eating and drinking; the pleasures of the affections higher than those of music; and the pleasure yielded by the approbation of a good conscience higher than all the rest? And how have we learned to conceive of aims of duty so high, that not even the highest pleasure, present or future, ought to be weighed against them?

The Sense of Holiness is a case of Intelligence.—I believe this moral sense, or sense of holiness, is incapable of being referred to any principle belonging to either matter, life, or sensation, and can only be explained as a case, not of vital but of spiritual Intelligence.

Mill on a Moral Element in Pleasure.—Mill, in his work on Utilitarianism, maintains, with the whole of the philosophical school which he so ably represents, that the moral sense is

a secondary feeling, and produced by association with the pleasures and pains of sensation. He is, however, obliged to admit—or rather, I ought to say, he places in the front of his theory—that besides differing in quantity (which, I suppose, means intensity multiplied into duration), pleasures differ from each other as higher and lower; a little of a higher pleasure being worth as much as a great deal of a lower one. Of course I agree with this; but it destroys the whole theory;—it introduces an ethical element into the subject without saying whence it is derived, and thereby virtually confesses that it is underived. As Mr. Laurie remarks, "the *greatest* happiness theory is at once transformed into the *highest* happiness theory."[1]

I have only glanced at this most important subject. It would be impossible to do it justice without introducing arguments drawn from another world than that external world which we know through the senses; and to do so would be to enter on a totally new class of subjects. It is not from indifference to them, but rather from a sense of their transcendent importance, that I at present pass them by with this allusion. I have treated this subject more fully in my *Scientific Bases of Faith*, and I shall have to speak of its connexion with moral freedom in the chapter on Automatism.

[1] Laurie's *Notes on Moral Theories*, p. 103.

CHAPTER XXIX.

MENTAL DEVELOPMENT.

Analogy between Organic and Mental Development.—In the chapter on Mental Growth,[1] we traced the analogy, which we showed to be much closer than is commonly seen, between mental and organic growth. In the present chapter we have to show a similar analogy between the development of the organism out of a simple germ, and the development of Mind out of the germ of sensation. The organism is a mass of vitalized matter having very complex structure, and is developed out of a minute structureless mass of gelatinous substance; and, similarly, the complex aggregate of the mental functions is developed out of sensation. The bodily organism is a congeries of organs and the mind is a congeries of functions, but the relation of functions to each other in the mind is analogous to the relation of organs and functions to each other in the body.

Development is differentiation of unlike parts.—All development, mental as well as bodily, is differentiation; and in describing any process of differentiation, it is difficult to avoid the use of language which appears to imply that differentiation signifies branching out. But this is an inaccurate metaphor. The differentiated organs and tissues of an organism do not branch out and separate; on the contrary, the more complete is their differentiation, the more complete also is their

[1] Chapter XXVI.

integration; that is to say, the more unlike they become, the more perfectly their functions are combined, and the more necessary they are to each other's life. As stated in the chapter on the Direction of Development,[1] the more complete is the physiological division of labour, the more complete is also the physiological centralization. It is the same with the mental functions. Consciousness, thought, and will are distinct functions, but they are necessary to each other's development. Thought derives all its materials from consciousness, and furnishes consciousness with the materials of all the higher emotions. Will is directed by thought and accompanied by consciousness. Will has also the power of directing thought; this power is what makes possible that process of thought called abstraction, on which the immeasurable superiority of the reasoning power of man to that of all animals appears to depend.

Intellect, Emotion, and Will are developed from the germ of Sensation.—Mind is developed out of Sensation. Sensation determining consciousness is the germ of Intellect and Emotion;—Sensation determining muscular action is the germ of Will.

The consciousness of the qualities of sensations as agreeable or disagreeable is the germ of the emotional nature.

The cognition of the relation between sensations—their co-existence or succession, their relative position in space, and their likeness or difference—is the germ of Intellect.

Memory.—Intellect has two distinct developments; to one of them belong Memory and Imagination, to the other Perception and Reasoning. These respectively correspond to the sense of Personality and of Individuality, as expounded in Chapter XXVII. In that chapter we have seen that the germ of Memory consists in the tendency of the impression made by a sensation on the consciousness to outlast the sensation itself; and fully developed memory consists in the liability of impressions to be recalled

[1] Chapter VI.

into consciousness. This takes place under the law of mental habit, or the association of ideas: an impression on the consciousness recalls to memory another impression which has become habitually associated with the first; as when the sound of a friend's voice recalls the image of his face. This is true not only of feelings of sensation, but equally so of those classes of impressions on consciousness which have their source within the mind itself;—in other words, the law of memory by association is equally true of sensations, of emotions, and of thoughts. By the establishment of such associations, it becomes possible for one sensation or thought to produce not only the consciousness of itself, but also the revived consciousness, that is to say the memory, of another. Without this process, thought would have no materials. And not only may one impression on consciousness call up the remembrance of another, but that remembrance may call up another remembrance; and this may go on for an indefinite number of times. Reverie may perhaps be defined as consisting in the succession of remembered images thus calling one another into consciousness, without the guidance of the will. It is impossible to doubt that in a great number of cases the intermediate links of association are unaccompanied by consciousness; in no other manner can we account for the strange way in which absent and long forgotten things will often come back to memory. This unconscious suggestion is the rudimentary form of unconscious thinking.

Recollection or Voluntary Memory.—The next stage in the development of memory is recollection, or the recalling of remembrances, not by the involuntary process of mere suggestion, but by a voluntary act; as when, in answer to a request, we relate what we have heard. It is within every one's experience, that a considerable effort of will is often needed in order to recall what we wish to remember. Recollection is a higher development than mere memory, and, like all higher developments, it is later acquired. Children often remember tenaciously before they can recollect. This is the reason of a fact

which is well known to every one who has had much intercourse with young children; namely, that they enjoy hearing a story told over and over again, even when they know it so well that they can correct any mistake in it. They remember the story without being able to recollect it. Something of the same is to be observed among uneducated adults; indeed, the power of recollection is probably in no case equal to the power of remembrance. The power of remembrance is often perfect; as in performing a piece of music from memory. But the power of recollection appears never to be perfect; if it were, the recollection of music would produce as strong an impression on the consciousness as the music when actually heard; and this probably never occurs, except in that class of waking dreams of extraordinary vividness which approach to hallucination.

Imagination. — We have now traced the development of memory, from the mere retaining of impressions on the consciousness, up to the voluntary recollection of them. A higher stage of what is really the same development consists in imagination, or the formation of new combinations, by the action of the mind itself, out of the materials furnished by memory. The mind cannot create; it can only combine and recombine. Memory must furnish the materials for imagination to work on. The Greeks, in the language of allegorical fable, or rather allegorical truth, called the Muses the daughters of Mnemosyne.

Summary.—There are thus four stages of the development of the powers of Memory and Imagination:—

1. Continuance of an impression in consciousness after it has vanished from sensation.
2. Memory by association.
3. Voluntary memory, or recollection.
4. Imagination, or recombination of remembered impressions by the action of the mind, sometimes voluntary, sometimes involuntary and spontaneous.

Development of reasoning out of the cognition of relations.—Side by side with the development of the powers of Memory and Imagination, proceeds the development of the reasoning power. As the germ of memory is the power of the consciousness to retain the impression of a sensation after the sensation itself has vanished, so the germ of the reasoning power consists in the power of cognizing the relation of different sensations one to another.

Cognition.—It is to be observed that the cognition of simple relations is presupposed in the formation of associations of ideas. Association by contiguity presupposes that the mind cognizes the relation of contiguity, whether in space or in time; and association by likeness, in the same way, presupposes that the mind cognizes the likeness.

Perception and Simple Inference.—The first stage in the development of thought is thus the cognition of relations: the second is the perception of objects: the third is that lower form of reasoning power which we have in common with animals. This may be defined as merely reasoning from one object of sense to another, or simple inference; it consists in the power of making such inferences as this, that a man must be in the house because his hat is on its peg.

Power of directing thought at will. Abstraction. Man's superiority in reasoning.—The next stage of the development of thought is the distinctively human power of reasoning. I am not able to see any way of referring all the superiorities of Man to any single principle. But so far as the superiority of Man to the highest of the animals is intellectual, it is traceable to his power of directing thought at will. On this depends the power of abstraction; and with it, the power of using words and other arbitrary signs in speaking and in thinking.

It must however be observed, that the germ of these powers consists in the power of Attention, which is not distinctively human,

but is possessed by the more intelligent animals. Attention may be defined as the action of the mind in directing consciousness and perception; it is a lower development than the voluntary direction of thought, inasmuch as perception is a lower development than thought; and the attention of which an animal is capable—as for instance that of a carnivorous animal watching its prey—is perhaps rather automatic than truly voluntary.

Language.—It was a favourite doctrine with Archbishop Whately, that "language is not only the expression of thought but the instrument of thought;" and he maintained that it is impossible to carry on any reasoning process except by the aid of words, or other signs, such as the figures of arithmetic or the letters of algebra. And I believe he maintained also, that the power of using such arbitrary signs as instruments of thought is the distinctively human power, and is at the root of Man's intellectual superiority to the lower animals.

There can be no doubt that this is correct as to the facts. It is possible to make such an inference as that a man must be in the house if his hat is on the peg, without the use of words in the process; and many dogs are perfectly able to draw such an inference as this. But no one who examines any reasoning process of a much higher kind than this, as it goes on in his own thoughts, will doubt that we think in words; and that if we were debarred from the use of words in thinking, no elaborate process of thought would be possible to us. The power of making use of words or other arbitrary signs for the purpose of thinking, cannot be an independent and primary power; it must be the result of something simpler and deeper; I should think so, even if I were unable to carry the analysis any further. But it is a result of another power, which constitutes the really primary and fundamental difference between the intellect of man and that of the animals which most nearly approach him; namely the power of directing thought at will. Thought is impossible without the formation of associations: indeed, all thought which is higher than the cognition of the simplest relations consists in

forming new associations. In forming associations the mind is at first in a merely receptive state, but it soon becomes active, and one of the most important results of its activity is the formation of language by a voluntary, though probably only half-conscious, act of the mind.

Abstraction. Instance in Arithmetic.—A second result of the power of directing thought at will is the power of abstraction. Without abstraction none but the most rudimentary process of thought would be possible. An example may best serve to make this subject clear, and the best example I can think of is that contained in elementary arithmetic. The multiplication table is the statement of a set of abstract truths—truths, that is to say, which can only be arrived at by abstracting in thought the relations of number from the ideas of all the things that are or can be numbered. In saying that eight times eight are sixty-four, for instance, we have nothing to do with any things that may count up to the number of sixty-four ; they may be books, or cattle, or tiles, it matters not : we only make an assertion concerning the abstract numbers eight and sixty-four. Thus in thought and in language to abstract a particular set of the relations, or of the properties, of things from the things themselves, is what mere suggestion, working by the laws of association, could never do ; only a voluntary act of the mind can do it.

Voluntary action is later developed than involuntary.—In reasoning as well as in memory, the voluntary action of the mind is a later and a higher development than its spontaneous action. Voluntary recollection is higher than spontaneous remembrance, and voluntarily directed thought is higher than spontaneous thought. The same is also true of motor action : voluntary motor action is a later and higher development than consensual action.

Self-consciousness.—In close connexion with the distinctively human power of directing thought at will, is the distinctively

human faculty of self-consciousness. All animals with a well-developed brain are probably conscious of their own feelings, but only Man is conscious of himself. Self-consciousness may be defined as consciousness of consciousness;—it is related to primary or simple consciousness, as this latter is to sensation. The use of the personal pronouns is the product and symbol of self-consciousness. We shall return to this subject in the following chapter.

Moral Nature developed out of the sense of Pleasure and Pain.—Concerning the development of the moral and emotional nature it is only necessary to state again, in a slightly different form, the results we have arrived at in the preceding chapter. The germ of the whole moral and emotional nature is the sense of pleasure and pain in mere sensation. Out of the sense of pleasure and pain as actually felt, arise desire and fear; and out of the desire and fear of present things, such as desire for food or fear of a wild beast, arise care for the unseen and distant future; and hence the virtue (for it is a virtue) of prudence. At the same time, new emotions are produced by the action of association, which attach themselves, not to the immediate pleasures and pains of sensation, but to objects which have become habitually associated with these. The love of money is the best instance of this; it has evidently been produced by the association of the idea of money with the idea of the desirable things that money can obtain for its owner; for money is desirable, only on account of the desirable things it will obtain. Selfish as this passion usually is, it belongs to a more highly developed mental nature than that which cares only or chiefly for the enjoyments of mere sensation. I have mentioned the love of money, because it is by far the most remarkable of the class; but these feelings of association may attach themselves to almost anything, and sometimes do attach themselves very closely to places, and to objects which may have no beauty, and no value except as mementoes.

Sympathy.—Next in the scale of moral development are sympathy and the social affections. Out of the desire of good and the fear of harm for oneself, arise the desire of good and the fear of harm for others; and this, in Man, becomes the root of patriotism, philanthropy, and all the unselfish virtues.

Love of beauty, of knowledge, and of holiness.—The last and highest kind of moral development consists, in its rudimentary form, of those affections which are not to be referred, either directly or (as I believe) indirectly, to the pleasures and pains of mere sensation: the most important of these are the love of beauty and the love of knowledge. Higher than these, but on the same line of development, is the moral sense—the love of holiness, and the fear and hatred of sin. We have spoken of this subject at greater length in the preceding Chapter.

Summary.—We have now to state in a tabular form the various kinds and directions of mental development, with the successive stages of each. It will be seen that the principle of this table is the same as that in the chapter on Organic Functions.[1] But as the use of such a tabular statement is not to communicate information or ideas in the first instance, but to give a concluding summary of them, it may be well first to state its substance in an ordinary paragraph.

Sensation may produce no effect beyond itself, or it may produce consciousness, or it may produce action. Consciousness is either intellectual or emotional. The intellectual nature has two distinct developments, one in the direction of Memory and Imagination, the other in the direction of the reasoning power. The germ of Memory is the continuance of the consciousness of sensation after the sensation itself has ceased: this successively develops into Memory by suggestion, voluntary Recollection, and Imagination. The germ of the reasoning power is the cognition of such simple relations as likeness, succession, and position: this successively

[1] See p. 85.

develops into perception of things, the power of simple inference, and the power of abstract reasoning. The germ of the emotional nature is the sense of pleasure and pain in mere sensation; this develops into the following, namely, desire and fear; the emotions due to association, such as the love of money; the sympathetic emotions; the love of beauty and of knowledge; and the moral sense or sense of holiness. When sensation produces action, this, in its simplest form, is consensual action; and this successively develops into the voluntary direction of muscular action, and the voluntary direction of thought.

Co-operation of mental factors.—In the tabular statement the same function is really, though not in so many words, enumerated twice under different heads; thus, Imagination cannot be separated from the voluntary direction of thought, and the moral sense belongs to the rational nature as well as to the emotions. This is true, but it is not the result of any error or oversight; it is inherent in the nature of the case. "More complex is more perfect," [1] and in the highest mental functions Feeling, Thought, and Will are inseparably combined.

[1] Tennyson's *Palace of Art.*

Tabular Statement.

Sensation	Determining Consciousness	Primary.	Intellectual	Mnemonic.	Continuance of consciousness after sensation is past.
					Memory by suggestion or association.
					Voluntary recollection.
					Imagination.
				Rational.	Cognition of simple relations.
					Perception of objects.
					Simple inference.
					Abstract reasoning.
			Emotional.		Sense of pleasure and pain.
					Desire and fear.
					Emotions of association (*e.g.* love of money).
					Sympathetic emotions.
					Love of beauty and love of knowledge.
					Moral sense.
		Secondary.			Self-consciousness.
	Determining Action.			Muscular.	Consensual action.
					Voluntary action.
				Mental	Attention.
					Voluntary direction of thought.

CHAPTER XXX.

MENTAL INTELLIGENCE.

Intelligence shown in the use of the personal pronoun.—We have argued in previous chapters of this work, that in organization, and in the motor instincts, there is an element of Intelligence not to be resolved into unintelligent elements; and we have now to maintain the same of the Intelligence which is manifested in thought. In speaking of Instinct, we dwelt on a few special cases, such as that of Huber's bees that constructed little waxen buttresses to steady the honeycomb on an uneven floor[1]—an action which could not have been learned by mere habit, because similar cases cannot have occurred sufficiently often in the life of the animal or its ancestors to form the habit. We also pointed out the special difficulty in such cases as that of the Bee and the Ant, where the effect of Habit cannot accumulate by inheritance, because the working insects, which alone manifest the constructive instincts of the species, do not propagate. We shall commence the argument respecting Mental Intelligence with an instance in some degree similar to these; an instance, namely, where every sane human being learns what it is demonstrably impossible that he should learn by mere habit, acquired in the usual way, through imitation. The instance I mean is the use of the personal pronoun.

Professor Ferrier on this Subject.—"The child's employment of language, previous to his use of the word *I*, may be accounted

[1] See p. 421.

for upon the principle of imitation. He hears other people applying certain sounds to designate certain objects; and when these objects, or similar ones, are presented or in any way recalled to him, the consequence is that he utters the same sounds in connexion with their presence. All this takes place under the common law of association. But neither association, nor the principle of imitation, will account for the child's use of the word *I*. In originating and using this term, he performs a process diametrically opposed to any act of imitation. Take an illustration of this. A child hears another person call a certain object a table;—well, the power of imitation naturally leads him to call the same thing, and any similar thing, a table. Suppose next, that the child hears this person apply to himself the word *I*. In this case too, the power of imitation would naturally (that is to say, letting it operate here in the same way as it did in the case of the table,) lead the child to call that man *I*. But is this what the child does? No; he still applies the word table to the objects to which other people apply that term; and in this he imitates them. But with regard to the word *I*, *he applies this expression to a thing totally different from that which he hears all other people applying it to*."[1]

This alone appears to be sufficient proof that, in the human Intelligence at least, there is an element not derived from unintelligent Habit or Association, or from the equally unintelligent impulse to imitation; for although habit and imitation, acting without an independent element of Intelligence, will no doubt account for the child learning the sound of the word *I* as it learns that of any other word, they will not account for his learning to use it in the right place.

[1] The above is from Prof. Ferrier's "Philosophy of Consciousness" (*Philosophical Remains*, vol. ii. pp. 110, 111). I have omitted parts of some sentences, and the italics are mine. Ferrier insists on the truth that the use of the personal pronoun proves not only Intelligence, which animals share with us though in a lower degree, but self-consciousness, which appears to belong to Man alone. But we have at present to do with it only as a proof of the underived nature of Intelligence; and this also agrees with Ferrier's view.

Intelligence shown in the power of Belief.—This proof is a special one, like those derived from the instincts of particular species of animals. But we have now to mention, as proof of the underived nature of mental Intelligence, a fact which is not special, like the use of the pronoun, but co-extensive with Mind; I mean the power, or capacity, of Belief. It has often been admitted that Belief is a difficulty of the theory which would refer all mental facts to the association of ideas. We maintain Belief to be not merely a difficulty of that theory, but its refutation.

Belief in things Past, Future, and External.—Belief is defined as having for its object something not immediately present to consciousness; something either past, or future, or external. We shall speak further on of belief in the existence of an external world. We have first to speak of belief in the past and in the future.

Memory and Expectation are more than mere Impressions.—Belief does not enter into the mere consciousness of present feeling; but memory of the past and expectation of the future are beliefs;—Belief enters when we recognize the reality either of the past or of the future, as distinguished from the present.

Germ of Memory and Expectation in associated feeling.—The germ of both Memory and Expectation consists in associated feeling; such an association, for instance, as that between the sound of a man's voice and the sight of his face. If I hear a man's voice and remember where I last saw his face, this is Memory. If I hear his voice and expect to see his face the next moment, this is Expectation. Memory refers to the past and Expectation to the future; but the germ of both is in the association which makes me think of the face when I hear the voice. The mere association contains no element of Belief; the impression of the face on my consciousness is only a revived

impression of what was once present to my sight. But in memory there is more than this; there is also a belief that the present impression of the face on my consciousness represents an impression which, at some former time, was present to my sight. Similarly, expectation of the future is something more than merely the ideal awakening in consciousness of anticipated feeling through the action of association or imagination;—expectation consists of such anticipated consciousness, combined with a belief that it represents a future reality. The element of Belief is what distinguishes Memory and Expectation from mere imagination or reverie.

Belief needs Intelligence.—Now, the laws of Habit will not account for this. Habit, acting according to the laws of Association—that is to say the powers whereby mental impressions are received, retained, revived, and combined—will account for the formation of conceptions, so long as these are without reference to anything external to consciousness; but not for the formation of the belief in a reality which is either past, or future, or external, and consequently is not included within the immediate consciousness. In other words, the laws of mental habit will account for the power of conceiving, but not for the power of believing. Belief needs Intelligence; no unintelligent agency, no modification of the merely sentient faculties through the action of habitual association, will account for the power of conceiving of anything as a reality when it is not immediately present to consciousness; and it is the entrance of this conception that first makes thought rational. Without this conception, we should not be rational; we should be merely sentient, and conscious to the extent of being conscious of our sensations; but we could not be conscious of Self or Personality, because, as we have already seen,[1] Personality, or the permanent element in consciousness, is distinguished from the changeable element of feeling only by means of Memory; and Memory involves belief in a reality which is no longer present.

[1] See p. 446.

Ultimate nature of Memory and Expectation.—The belief in the reality of the past involves, or rather is indentical with, the belief in the veracity of memory ; and this, as Mill has admitted in his *Examination of Hamilton's Philosophy*, is "evidently ultimate," and not resolvable into Habit or any other principle. A belief which is thus an ultimate fact, can be referable only to Intelligence. The same is true of the belief in the reality of the future which is implied in Expectation.

Mental activity in Belief.—It is important to observe also, that Belief involves not only Intelligence, but mental activity. Were the mind in a merely receptive state, impressions, even though remaining from the past, would appear to the consciousness only as present impressions. The belief in the reality of the past, and, with it, in that of the future, arises with reflection, which is a form of mental activity. Without this, Memory and Expectation would never be developed out of their germ, which, as we have seen, consists in mere associated, revivable feeling.

In what sense Belief is due to Habit.—In reply to what has been said about the Intelligence necessarily involved in Belief, it may be urged that, as a matter of fact, Belief is in many cases obviously determined by habit alone. Most men have beliefs, especially on religious and political subjects, which have no ground whatever except habit, originating usually in education. This is true : but it only shows that Belief, like every other mental function, is subject to the laws of Habit, and consequently that particular beliefs may be determined by Habit ; it does not show that the laws of habitual association are capable of accounting for the general fact that the mind is capable of Belief. This distinction may be illustrated by an analogy drawn from the simplest of the physical sciences. The action of all forces is governed by the laws of motion, and yet the laws of motion will not account for the origin of force ; just so, the formation of beliefs, like all other mental actions, takes place subject

to the laws of habitual association, and yet it does not follow that Association is of itself able to produce Belief.

Intelligence necessary to Perception.—If Intelligence, acting in Belief, is thus necessary to the memory of the past and the correlative sense of Personality, it is no less necessary to the perception of the external world and the correlative sense of Individuality.[1] This subject opens the question of the nature of Perception.

Perception is less simple than Memory.—We have spoken in a previous chapter[2] of the cognition of Time and Space; and we have there seen that while the cognition of Time has been generally taken as an ultimate fact, the nature of the cognition of Space has been much controverted. This is obviously connected with another fact, namely that while the veracity of Memory, and our belief in it, have been generally accepted as ultimate facts, the nature of Perception and the ground of the belief in the external world whereof it testifies, have been much controverted. The reason is the same in both cases; the cognition of Time is a simpler act than that of Space, and Memory is a simpler function than Perception.

Perception is to be understood by resolving it into its elements.—If we wish to understand a complex function, we must separate it into its component functions;—experimentally if this is possible, ideally if it is not possible. When this is done with Perception, we shall find the difficulties of the subject appear comparatively manageable.

The difficulties that surround the question of Perception have moreover been greatly increased by its becoming complicated with other questions, kindred no doubt, but separable from it, concerning the relation of the mind to Space, and the relation of the two senses of sight and touch to each other in the act of Perception.

[1] See p. 447. [2] Chapter XXVII.

Ambiguity of "the external world."—It is worth while to clear up the ambiguity of the expression "the external world." What is this understood to be external to? To the mind, or only to the body? In other words, is the body part of the external world? This question is only verbal. We define the internal world as consisting of all that is known by internal consciousness; and the external world, as including all that is known by external perception. In so far as the body is the seat of sensations, it is part of the internal world: in so far as it is an object of perception, it is part of the external world. It is here to be observed, that when one of our organs of sense becomes an object of Perception, it is perceived, not by itself, but by another organ of sense.[1] The eye cannot see itself, but the hand can feel it; one hand, or at least one finger, cannot feel itself, but the other hand can feel it, and the eye can see the hands.

Consciousness, Cognition, and Perception. Perception is a rapid Inference.—Another source of difficulty is that involved in the question, What is the object of Perception? Is it sensation, or the relation between sensations, or the object to which we refer a sensation? This also is not a question of fact but of definition; and the answer depends on the definition of the word Perception.[2] According to the use of words that I prefer, we are conscious of sensations, we are cognizant of the relations between sensations, and we perceive objects. Consciousness and Cognition are simple acts, and do not involve belief in a world external to consciousness; but Perception is an inference, wherein from sensations we infer the existence of objects,

[1] See "A Speculation on the Senses," in Ferrier's *Philosophical Remains*, vol. ii.

[2] It is scarcely necessary to refute the fantastic notion that the object of visual perception is the retinal image. It is a strange use of words to call anything an object of perception, whereof the existence is never made known in perception. It would perhaps be possible to frame a definition of perception which would be consistent with this notion; but, besides the objection to changing the received sense of a word, it would be most confusing to give the name of *the object of visual perception* to something which has no analogue in any other sense.

external to consciousness, to which we refer the sensations as to their source. I propose to define Perception as an instinctive mental act whereby we refer sensations to their sources in the external world.

The view that Perception differs from what is usually called inference only in being unconsciously performed, is supported by the fact that the same act may appear to be a perception or an inference, according as it is performed at once and spontaneously, or with hesitation and with some effort of thought. Thus, dogs perceive by the smell. A dog will smell a dead animal and perceive at once where it is, when a man may ascertain its presence only by considering for some little time what the source of the unpleasant smell can be, and even then may remain in some degree of doubt. It is impossible to point out any difference between the dog's unhesitating perception and the man's hesitating inference, except that the one is instantaneous, while the other occupies an appreciable time. We can perceive by sound as accurately as the dog can perceive by smell, and we can perceive the presence of our friends by their voices; but this is altogether an acquired perception, depending on habitual association: when we are learning to know a man by his voice, the power of identifying him graduates from hesitating inference to unhesitating perception; and when it has become perception, it is accompanied by no more conscious thought than the spontaneous perceptions of an animal. And when inferences, which are indisputably so, are performed at once, spontaneously, and without effort, we speak of them as perceptions. David *perceived* that his child was dead, when he saw the servants whisper.

Mental and bodily Activity both necessary to Perception.—It is to be observed that the power of sensations to give rise to perceptions comes into existence only through the activity, both mental and muscular, of the conscious organism. So long as consciousness remains in a merely receptive state, and the voluntary muscles are at rest, it appears doubtful whether any sensory

impressions could ever give rise to the conception of a world external to self. But when the animal puts forth voluntary muscular energy and finds this resisted, the conception arises, and the fact is discovered, of an external world, and of the individuality of the self which is distinct from that world;—self is made known as exerting force, and the external world as resisting it. The knowledge of self belongs to consciousness; the first spontaneous and rudimentary knowledge of the external world is called Perception. Hence arises that dualism which runs through all thought, between self and the external world, mind and matter, internal consciousness and external perception and observation.

Logical element in Perception.—Perception, though an unconscious process, is thus a logical one. We have defined it as a process whereby the mind infers the existence of something external to itself; and this inference is made according to logical principle. The process may be thus expressed:—"This force which I feel, is not exerted by myself; it must therefore be exerted by some agent outside of myself." This is an application of the law that a contradiction cannot be true; for it would be a contradiction if a force exerted from without were also exerted from within.

Metaphysical element in Perception.—But this is not a full account of the subject; for why do we refer force to an agent at all? In other words, why do we conclude, from the fact of resistance, the existence of resisting objects? I reply, that as in becoming conscious of feelings we become conscious of a self which has the feelings, so in becoming conscious of forces that resist our own voluntary motions, we infer the existence of agents, or objects, to which we refer the forces.

In this we assume the truth of the axiom that properties imply substance; or, what I think a better statement of it, that action implies an agent;—I regard this as the fundamental axiom of metaphysics, holding therein the same place which the

impossibility of a contradiction holds in logic. The question whether substance, or agency, has any other meaning than mere permanence, is a parallel one to the question whether causation has any other meaning than mere succession. In speaking of the relation of the mind to causation,[1] we have endeavoured to show that the essential point in causation is not succession, but force.

This analysis of Perception will have no weight with those who agree with Mill in reducing the idea of material substance to that of mere permanence, and in thinking it a sufficient account of the external world to say that it consists of "permanent possibilities of sensation," which have, or may have, no existence apart from the mind that perceives them. But they will agree—indeed this is, if possible, more necessary to their theory of Perception than to ours—that without the memory of past sensations and the expectation of future ones, we could have no idea of an external world.

Intelligence needed to learn that other human beings are conscious.—But how do we acquire our knowledge, or belief, that the human beings surrounding us are conscious and rational like ourselves? It is obviously an inference, though spontaneously made at an age when thought has not yet become conscious of itself. But it is an inference, which, more obviously than any other inference, mere habitual association could never make. It is true that I associate my own actions with my conscious self, and thence learn to associate the actions of other human beings with the thought of their conscious selves. This is all plain sailing, so soon as I have formed the idea that the universe may possibly contain another being like myself. But this idea will never be engendered by any habitual association among my own feelings. So long as my nature remains merely sentient and conscious, it is its own universe, and cannot conceive of any consciousness but its own. Only an intelligence not derived from Habit can enable it to do this. This argument is

[1] See p. 456.

not affected by the fact that animals learn the same truth, for all living beings are intelligent in their degree.

Defence of Natural Realism.—In the foregoing analysis of Perception I have sufficiently avowed myself a Natural Realist. I am a Realist, because I believe, as a truth at once of science and of faith, that we live in a world of realities and not of phantoms; and that the function of philosophy is to interpret, and thereby to justify, the spontaneous dicta of consciousness. And I am a Natural Realist, because the facts of organic and mental science teach that Intelligence acts spontaneously. The mental judgments of men and animals, which affirm the reality of the past and the future and the existence of the external world, are unconscious and organic, like the growth of the tissues and the circulation of the blood. The self-conscious understanding may, or may not, be able to find a logical justification for these judgments; but this matters nothing whatever to their validity; its dicta are mere afterthoughts.

Bain's theory of Belief.—Professor Bain, who is one of those who endeavour to account for all mental facts by the laws of Association, maintains that Belief is a result of association, with the addition of an active element. That is to say, if I understand him aright, Belief is the mental state of an animal which is preparing to act;—of a carnivorous animal, for instance, which is going to spring on its prey. This assumes that Expectation is the elementary form of Belief, and that Memory is developed out of it. We cannot accept such a view. At least as strong an argument might be made out for fixing on Memory as the primary form of Belief;[1] but I do not see any convincing reason for thinking that either Memory or Expectation is more elementary than the other.

Bain's theory of the subject, however, suggests the important truth that Belief depends on the mind's activity. We have seen

[1] See "Knowledge and Belief," by Daniel Greenleaf Thompson, in *Mind*, of July, 1877.

that the mind is incapable of belief in anything either past, future, or external, so long as it remains in a merely receptive state;—that a sense of past and future comes with mental activity in reflection, and a sense of an external world with will and the exertion of muscular force.

Predominance of Belief in early life.—The only real argument against the theory of Belief here propounded is, I think, the fact that at the beginning of our mental development, when the mind is comparatively, though not absolutely, in a passive state, we have not less but more belief, in the sense at least of credulity, than in our later life. It is indeed a familar fact that children and primitive men believe everything, and that doubt comes later. The explanation of this appears to be, however, not that Belief is intenser at an early period, but the reverse;—the absence of doubt in the child's mind is probably a partial continuation of an earlier infantile state, in which Belief and Imagination are not separated from each other at all. The facility with which young children "make believe" is not a proof of intense Belief, but, on the contrary, of the weakness with which they discriminate between Belief and Imagination. Belief and doubt, being logical contraries, are each of them known only through the other; and the saying of religious moralists, that "he who has never doubted has never truly believed," expresses a psychological truth.

Summary of Chapter.—In the present chapter we have seen that there is a special fact of the human mind which sets the theory of mere Association at defiance, and can only be referred to an Intelligence which is not resolvable into Habit;—namely the power which manifests itself in the use of the personal pronoun. We have seen further that there is a general fact of all mind, namely Belief, for which also mere Association is unable to account, and which is due to Intelligence in combination with the mind's activity.

CHAPTER XXXI.

THE PHYSIOLOGY OF MIND.

HERE the present work might end; for its primary subject is not organisation but function; and we have completed the task of tracing, in extreme outline, the relation of Intelligence to Habit throughout the formative, the motor, and the mental functions. We go on, however, to add the following on the physical character of nervous action, and on the relation between the mental functions and the organisation of the brain.

Indivisibility of Consciousness. Its ground in Nervous Centralization.—We have first to remark that, so soon as self-consciousness is attained, the mind feels itself to be an indivisible unity. As a fact of consciousness this needs neither proof nor elucidation, but we have here to do with its physical ground;—which is, that, in all classes of animals, a highly centralized nervous system appears to be a necessary condition of the development of Mind. A mental nature, or any approach to it, appears to be developed only in the Vertebrata, and in the higher Arthropoda, especially Insects and Spiders. In all these classes the nervous system is not only complex but centralized;—those parts of it which dominate the rest being concentrated in the head. The nervous masses thus concentrated are in the Vertebrata called the brain; this is a very complex organ, or rather a congeries of organs.

Intransmissibility of Consciousness.—Consciousness, which is not divisible, is also not transmissible. Almost any unconscious

habit may become hereditary; but, though Memory, as we have seen, is conscious Habit, it is never inherited. Habits which have been formed by the conscious acts of the parents may be transmitted to the offspring, but the offspring inherit no consciousness, or memory, of the acts which formed the habit in the parent. Thus, birds on uninhabited islands show no fear of Man, but after they have become a mark for the sportsman for some time they acquire a dread of him, and this instinct becomes hereditary. We cannot suppose that the birds which inherit this fear of Man have any conscious memory of their ancestors having been frightened by Man;—they inherit the fear, but not the consciousness of its cause. Selection will, no doubt, increase this tendency, by the less timid birds being killed, but the main cause is evidently hereditary habit. A still more remarkable instance of the same kind "was observed by Mr. Knight, that the young of a breed of springing spaniels which had been trained for several successive generations to find woodcocks, seemed to know as well as the old dogs what degree of frost would drive the birds to seek their food in unfrozen springs and rills."[1] In this case conscious knowledge appears to have become hereditary, though we cannot believe that there is any conscious memory of the ancestral experiences whereby the knowledge was attained.

Suggested reason of the fact.—It is possible that the intransmissibility of consciousness may be connected with the fact that there is never any organic connexion between the nervous systems of the parent and the offspring.

Sensation and Mind depend on Nervous Currents.—The chief subject of the present chapter is the nervous mechanism whereon mental action probably depends. It is as certain as any truth of science can be, that sensation depends on nervous currents sent upwards from the organs of sense to the nervous centres at the base of the brain, and that muscular action

[1] Carpenter's *Mental Physiology*, p. 104.

depends on nervous currents sent downwards from the nervous centres to the muscles; and it is as nearly certain as anything can be which is not experimentally verified, that consciousness, thought, and will are due to similar currents in the nerves of the brain;—using the word brain in its common sense, to signify the entire aggregate of nervous centres above the spinal cord. But before discussing the special question of the mutual relation of the parts of the brain, we have to speak of the nature of nervous action in general.

The Nervous Current consists of Energy.—It is impossible to doubt that nervous currents consist not of matter in any form, but of energy, in a form somewhat resembling electricity though not identical with it.[1]

Probably Electric and Nervous Currents are discontinuous.—It seems moreover probable that all electric and all nervous currents are in no case absolutely continuous, but consist of a very rapid succession of momentary currents or waves. If this is true, it strengthens their analogy with heat, light, and sound. But they are capable of becoming for all purposes practically continuous.

Electro-dynamic Induction.—One of the most important properties of the electric current consists in the power of one current to produce another. Let two conducting wires, A and B, be placed alongside of each other (or, what is generally better, twisted together into a hollow spiral, but kept from metallic contact by some non-conducting substance). Let an electric current be allowed to flow along A for an appreciable time, and be then cut off: on the current beginning to flow along A, a momentary current flows along B in the *opposite* direction to that along A; and on the current ceasing to flow along A, another momentary current flows along B in the *same* direction as that along A. The most probable interpretation of these

[1] See p. 62.

facts is, that at the moment when the current begins to flow along A, the molecules of B are thrown into a state of elastic tension: the act of the molecules of B, in assuming the state of tension, constitutes the first current along B; and the second current (which, as stated above, is in the opposite direction to the first) is constituted by the act of the molecules of B, on the cessation of the current along A, falling back into their normal state.

Electric Excitation of Nervous Currents.—Nervous currents are capable of being produced, and of producing other nervous currents, in a manner which is in some degree similar to this. "Supposing the nerve supplying some muscle has been dissected out and cut in two, if this nerve is made part of an electric circuit, then, at the moment of completing the circuit, the muscle will contract;—but its contraction is only momentary;—to keep up muscular contraction, it is requisite to send through the nerve a quick succession of electric disturbances. If the nerve forms part of an electric circuit in which there is an apparatus for breaking and completing the circuit, then, at each completion of the circuit, the muscle contracts; and when the alternate breaks and completions follow one another very rapidly, the contraction of the muscle becomes practically persistent. This truth is demonstrable by experiment on a dead frog, and also by experiment on the living human subject." [1]

Resemblance between these two cases.—These two experiments give parallel results to this extent, that in the former the second, or induced, electric current is only momentary, and in the latter the nervous current is only momentary; and in neither case does a continued current in the inducing wire give any result.

Difference between these two cases.—We must not, however, press too far this analogy between the production of electric

[1] Spencer's *Psychology*, vol. i. p. 80. See also Carpenter's *Human Physiology*, p. 610.

and of nervous currents. Although these two phenomena—namely the production of one electric current by another, and the excitation of a nervous current by an electric current—have the one remarkable, and perhaps significant, point of resemblance which we have described, yet the *modus operandi* is different. In the first of the two cases, the induced electric current is produced at the expense of the current inducing it;—in other words, the energy of the induced current is subtracted from that of the inducing current. The relation of the nervous current to the electric current is different from this;—it does not consist in induction but in excitation;—the energy of the nervous current is not drawn from that of the electric current, but is probably supplied from the vital energy that was previously latent, or static, in the nerve, and perhaps in the neighbouring tissue.[1] The relation of the nerve-current to the electric current which excites it is thus not similar to the relation of the induced electric current to the inducing current, but rather to that of a current from a "relay battery" to the current which does not supply it with its motive power, but only turns it on.

Excitation of one Nerve-current by the commencement or cessation of another.—It seems probable also that there is a relation between one nerve-current and another, similar to that which we have seen to exist between the exciting electric current and the excited nerve-current;—that is to say, the commencement or cessation of a current in one nerve may excite a momentary current in another nerve. The analogy is not close, because the action of one nerve on another, whereof we have now to speak, is not generally direct like the action of electricity on a nerve, but takes place through the ganglionic mass with which both nerves are in connexion. Nevertheless I believe that it is real, and—though this is offered only as a hypothesis—that it shows the key to the physiology of consciousness. But before speaking of the functions of the brain, we must describe, in extreme outline,

[1] See p. 21 *et seq.*

the parts which constitute the brain and the rest of the nervous apparatus of the motor life.

Reflex action.—In the simplest nervous system that appears to be possible under the laws of life, there must be at least two fibres, meeting in a ganglion, and acting one on the other through it. The fibres consist of a white substance; that of the ganglia is grey and cellular. One of the fibres conducts the stimulus from the skin, or wherever its outer extremity is situated, to its inner extremity at the ganglion. The other fibre conducts the stimulus from the ganglion to the muscle in which it terminates, and thus causes the muscle to contract. This is what is called "reflex action;" the stimulus being, as it were, reflected from the ganglion. The action of the spinal nerves is of this kind. If the spinal cord of a vertebrate animal is cut through in the neck, so as to be unable to conduct stimuli to the brain, the nerves of the parts below the severance continue to respond to any irritation, and to produce the appropriate muscular actions, with greater energy than in the unwounded animal; and yet these nervous currents and muscular contractions are unaccompanied with sensation or consciousness. The same has been observed in human patients when the spinal cord had been severely injured;—tickling the soles of the feet causes violent kicking, though the patient is unconscious of either the sensation or the motion. In such a case the sensory nerve acts on the motor nerve through the ganglionic (or grey and cellular) substance of the spinal cord, without the stimulus being conveyed to the brain, which is the organ of consciousness and will.

Sensation is not primary. It probably begins with special sense.—In the simplest and lowest development of a nervous system, the action of the nerve-fibres on their ganglia is probably unattended by any sensation; and this, as we have seen, continues to be true of large parts of the nervous systems even of Man and the higher animals. Higher up in the animal scale,

sensation appears: the action of some—not all—of the nerve-fibres on their ganglia produces sensation. We cannot tell where it begins. I think it most likely that sensation begins where organs of special sense come into existence; and as eyes appear to be the most generally distributed of these in the animal creation, I think it most likely that sensation is nearly co-extensive with the possession of eyes. But this is incapable of proof: we have no certain criterion of its presence or absence.

Inscrutable nature of Sensation. Sentient and insentient nerves are histologically alike.—Sensation is in itself perfectly inscrutable. It is impossible that we can ever know how or why it is that the flow of a current of a peculiar kind of energy along a nerve to its ganglion should be accompanied by sensation. But we might have expected to find sensation the peculiar function of some particular kind of tissue, so that the presence of sensation might be inferred with certainty from its presence, and the absence of sensation from its absence. Such, however, is not the case. Some nerves and ganglia are sensory, others are not so; and the microscope, so far as we yet know, shows no difference whatever between the structure of the two. We thus see that the sensory function is not a primary or fundamental endowment of the nervous system, but has been added to its original functions in the course of development.

The spinal cord, which is the principal nervous organ of the insentient life, is the first to be developed in the embryo, and the sensory ganglia grow out of it. It ought to be stated that these ganglia do not appear to be the seats of sensation any more than the nerve-fibres. Sensation is produced when certain ganglia receive a stimulus from their nerve-fibres; but the ganglion is insentient if acted on by pricking or in any other way except through its fibres, and the fibres are insentient if they are cut off from their ganglia.

Sensory ganglia. Consensual action.—The sensory ganglia are situated within the skull, but are distinct from the cerebrum,

or true brain. Besides the ganglia of the special senses, there is among them a pair of ganglia called the *thalami optici*, which (notwithstanding their name) are believed to be the nervous centre for the sense of touch. In close proximity to the sensory ganglia is another pair of ganglia called the *corpora striata*, which are believed (though the subject is an obscure one) to be the ganglionic centres for the nerves of motion, in so far as

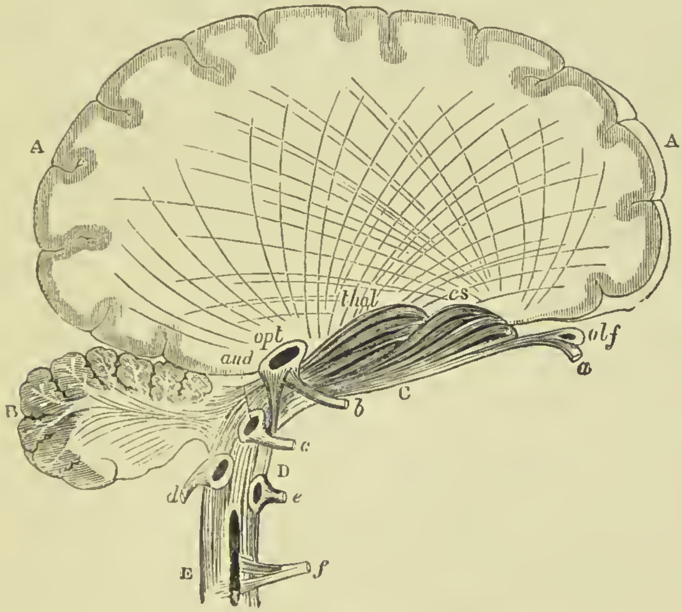


Diagram of the mutual relations of the principal encephalic centres, as shown in vertical section. From Carpenter's *Mental Physiology*.

A, cerebrum: B, cerebellum; C, sensori-motor tract, including the olfactory ganglion *olf*, the optic ganglion *opt*, and the auditory ganglion *aud*, with the thalami optici *thal*, and the corpora striata *c s*; D, medulla oblongata; E, spinal cord:—*a*, olfactory nerve; *b*, optic nerve: c, auditory nerve; *d*, pneumogastric nerve; *e*, hypoglossal nerve; *f*, spinal nerve. Radiating fibres of the medullary substance of the cerebrum are shown, connecting its cortical, or external, layer with the thalami optici and corpora striata.

motion is not merely reflex, but determined by sensation and will. The relation of these to the nerves and ganglia of sense is as follows:—An impression of sense is transmitted by some of the nerve-fibres of that sense to its ganglia, and the reception of the impression by the ganglia produces the sensation which is appropriate to that impression: the sensory ganglia, in their turn, act on the corpora striata, which are motor ganglia; and

the latter send down the motor nerves whatever motor impulse is necessary in order to make the appropriate response to the sensation. For instance: a flash of light falls on the retina, and the impression is telegraphed by the optic nerve to the optic ganglia, where it produces the sensation of light; the optic ganglia act on the corpora striata, and cause them to send a motor impulse to the muscles of the eyelids, which impulse closes the eyes, and thus makes the appropriate response to the impression of the flash of light. This is what Dr. Carpenter calls consensual action. The chain of cause and effect is exactly the same in consensual action as in merely reflex, except that in consensual action one of the links of the chain is sentient, and the motor action will not be produced unless sensation is felt.

Sensation at first is only the guide to action.—It will be observed that in the foregoing account of consensual action, sensation is described as existing, not by itself, but only as the intermediate link between impressions received by the organism from without, and the muscular actions that constitute the appropriate response to those impressions. Sensation existing by itself, and not necessarily leading to action, appears to belong to a higher development of life, and to be the preparation for Mind. The first and lowest functions of the nervous system appear to be purely reflex and insentient; these pass, by indistinguishable gradations, into consensual action; so that, at its commencement in the animal scale, sensation appears not to exist alone, but solely as the guide to muscular action.

The Cerebrum is characteristic of Vertebrata.—The nervous mechanism described above is all that Insects, or any other invertebrate animals, are known to possess. But in the Vertebrata a distinct organ appears, which is developed by budding out of the sensory ganglia, as they are developed by budding out of the spinal cord. This is the cerebrum, or true brain; it is also called the cerebral hemispheres, for it is a double organ,

though in Man and the rest of the highest animals the two hemispheres are in close contact. We have every reason to believe that on the cerebrum depend the existence of consciousness and mind, as distinguished from unconscious instinct. In Fishes, which are the lowest of the Vertebrate classes, it is very small in comparison with the sensory ganglia, but it increases in size as intelligence increases in ascending the animal scale, until in Man and the rest of the most highly organized animals the cerebrum is many times larger than all the rest of the nervous centres put together.

The Cerebrum is not in direct connexion with the organs of external life.—Its structure.—Like the spinal cord, the cerebral hemispheres contain masses both of ganglionic cells and of nerve-fibres; but, unlike either the spinal cord or the sensory ganglia, their nerve-fibres are not in direct connexion with any of the organs of external life—with either the muscles or the organs of sense. The cerebral hemispheres contain masses of fibres radiating upwards from the sensory ganglia and the corpora striata, and terminating in masses of ganglionic cells which are continuously spread out under the bones of the skull; and these ganglionic masses, both those of the two hemispheres and the various parts of the same hemisphere, are connected with each other by other masses of fibres.

Phrenological theory disproved by facts.—Concerning the functions of the different parts of the cerebrum, we have no direct evidence. We have no guide but analogy. With the help of analogy, however, I believe that a tolerably complete and satisfactory theory can be formed. It must first be mentioned that the theory of the so-called phrenologists is not only unproved, but disproved, by facts. According to that theory, the cerebral hemispheres consist of a congeries of organs, in each of which a distinct mental function is localized—comparison, imagination, firmness, love of children, &c. Were this true, injuries to the brain would injure the mind in definite ways, according to the

locality of the injury. But this is not the case; injuries to the brain appear generally to leave the mind unaffected, even when a part of the substance of the brain has been lost; and they certainly do not affect the mind in any way that can be predicted when the seat of the injury, and its magnitude, are known. Experiments on animals yield the same result. Phrenology, however, probably contains this much truth, that there is a tolerably close correlation between the form of the brain (which determines the form of the skull) and the mental character.

Nerves and nerve-currents of sensation and of consciousness.—We have seen that it is in accordance with the analogies of the nervous system, for a current along one nerve-fibre to determine the flow of a current along another fibre. Thus, if the impression of a flash of light is telegraphed along the optic nerve to the sensory ganglia, a motor impulse is telegraphed along another nerve, causing the eyelids to close. It seems probable that the nervous mechanism of consciousness resembles this. It is certain that sensation is produced by the flow of a current of nervous energy along a nerve-fibre of sense to its ganglion; the sensation of light, for instance, is produced by a current flowing along the optic nerve to the optic ganglia. Let us call this the *nerve-current of sensation.* Now, if consciousness is a feeling, which it certainly is, and if the consciousness of a sensation is a distinct thing from the sensation itself, as we have endeavoured to show;[1] it is as probable as analogy can make it, that the consciousness of the sensation is also due to a nerve-current, like that of the sensation, but in a different fibre; and if so, all the evidence we have leads to the conclusion, that the *nerve-currents of consciousness* are formed in the fibres that connect the sensory ganglia with the ganglionic substance of the cerebrum.

Is consciousness produced in the sensory ganglia or in the cerebrum?—A question arises here. The nerves of sensation

[1] See p. 426.

have ganglia at only one end; their other ends are in connexion with the organs of sense—with the eye, the ear, the skin, &c. But the nerves of consciousness have ganglionic substance at both ends; at one end are the sensory ganglia, at the other is the ganglionic substance of the cerebrum. Is consciousness produced in the sensory ganglia or in the ganglionic substance of the cerebrum? Is it due to the action of the nerves of consciousness on the former or on the latter?

The sensory ganglia are the probable seat of consciousness.—We can reason only from analogy, but the most probable opinion appears to be Dr. Carpenter's, namely, that the sensory ganglia are the seat of consciousness as well as of sensation; and that the function of the cerebrum is not consciousness, but thought, which may be unconscious. If this is true, then a sensation, and the memory, or revived consciousness, of the sensation, are both produced in the sensory ganglia, though by the action thereon of different nerve-fibres. This view is supported by the fact that a remembered sensation not only appears to the consciousness to resemble the original sensation, but often produces the same physical effects; thus, the nausea caused by a disgusting sight or smell is sometimes capable of being renewed by the recollection of the same. Moreover, there are many well-authenticated instances of "spectral illusion," wherein remembered or imagined images are indistinguishable from really visual ones; and it can scarcely be doubted that both the real and the imaginary images (to use rather inaccurate language), are due to impressions on the same ganglia.

Physical cause of consciousness and of memory.—This appears obvious enough as regards the memory of a past sensation; it is due to a current flowing from the ganglionic substance of the cerebrum down the nerves of consciousness to the sensory ganglia. And we believe all emotions, as distinguished from sensations, to be due to action of the same kind. But what are we to say as regards the consciousness of a present sensation? for this, as we have seen, appears to be distinct from the sensa-

tion itself. In reply I would suggest as probable that the nerve-current of sensation, which is the primary current, first causes a secondary current to flow upward along the nerves of consciousness from the sensory ganglia, which are the seat of sensation, to the ganglionic substance of the cerebrum, which is the seat of thought; and that the consciousness of the sensation is due to a current almost instantaneously reflected downwards along the same nerves from the ganglionic substance of the brain to the sensory ganglia. The mental action which is due to the upward current from the sensory ganglia into the cerebrum, is not consciousness, but memory, which consists in the registration in the ganglionic substance of the impression of sense. Impressions of sense which do not produce consciousness are not generally registered in the memory, only because when they are strong enough to leave distinct residua, and so to be registered, they are generally strong enough to excite reflected currents, and so to produce consciousness. But it seems probable that impressions may register themselves in the memory without being brought into consciousness.

It may be said that the supposed reflection of the current is a needlessly complex theory. I reply, that if any theory of the subject is possible, it is most probable that the memory of a sensation is due to an upward current flowing along the nerves of consciousness, from the sensory ganglia into the cerebrum, and there leaving a residuum which constitutes a registration in memory; and the recollection, or revived consciousness, of the sensation, is due to a downward current, along the same nerves, from the cerebrum to the sensory ganglia. This is Dr. Carpenter's theory, if I do not misunderstand him; and if it is admitted, there is no needless complexity but rather a needful simplicity, in supposing that the downward current, which produces the recollection or revival of a past sensation, is also that which produces the consciousness of a present sensation.

Consciousness not accompanying but following sensation.—This hypothesis appears to explain the fact that, in the case of sounds

at least, the consciousness of a sensation does not always accompany the sensation, but often follows it by a short interval. We occasionally become conscious, or aware, of hearing something said a few seconds before, and feel certain that if it were not thus seized at once it could not be recovered at all. In such a case, according to the physical explanation here offered, the upward current from the sensory ganglia outlasts the sensation; some change occurs whereof the cause is probably untraceable, but having the effect of heightening the activity of the cerebrum; and in consequence of this, the current is reflected downwards to the sensory ganglia, producing consciousness.

To the continuance of the same currents after the sensation has ceased is probably due the fact which we have noticed before,[1] that different successive impressions of sensation are capable of coalescing into a single impression on the consciousness; as when the sound of a word, which is really a succession of the sounds represented by the different letters, impresses the consciousness exactly as a single sound would do. A kindred fact is perceived in the case of sounds which are not continuously successive like those of the letters of a word, but recurrent. Thus in hearing poetry read, the expected rhyme produces on the consciousness a feeling of satisfaction, and its failure produces the opposite; yet, in the interval between the first and the second rhyme, no consciousness of the sound appears to remain. It may be said that this is only a case of memory, occurring after a very short interval; but the time during which the impression continues to be capable of recognition is so short—for the effect of the rhyme is lost if only six or eight lines intervene—that it seems more probable the *modus operandi* is different. In true memory, the impression is probably, as we have seen, registered in the ganglionic substance of the cerebrum, and it may remain for an indefinite time. In the case whereof we are now speaking, on the contrary, the impression has probably not been registered in the cerebrum, but consists in the continuing upward current from the sensory

[1] See p. 431.

ganglia to the ganglionic substance of the cerebrum along the nerves of consciousness; and the time—only a few seconds—after which a rhyme ceases to be spontaneously recognized, is a rough measure of the time during which the current in question continues to flow. The upward current remaining from the auditory impression of the first rhyme coalesces with and strengthens that which is set going by the impression of the second rhyme.

Physical distinction between Consciousness and Memory.—Consciousness was called by Dr. Brown a short memory. This recognises the truth that the consciousness of a sensation is not identical with the sensation itself; and we have seen that both consciousness and recollection are probably due to the re-action of the cerebrum on the sensory ganglia; but the difference appears to be, that in consciousness the secondary currents, which the sensory ganglia send upwards into the cerebrum, are simply reflected back to the sensory ganglia, without necessarily leaving any residuum, or permanent impression, in the cerebrum; and, consequently, if they are not reflected back during the few seconds before they cease to flow, they cannot be reflected back at all; while memory is due to a registration of impressions in the ganglionic, cellular, or grey matter of the cerebrum; which can, under favouring circumstances, determine currents along the nerves of consciousness downward to the sensory ganglia, reproducing the original consciousness of the impressions. The retention, or registration, of impressions, is probably a function of the ganglionic substance of the cerebrum alone.

Recurrent Vision.—The probability of such a reflection of the currents as we suppose, is strengthened by the remarkable fact of "recurrent vision," which appears to be due to a similar reflection of a nerve-current. Prof. C. A. Young, of Dartmouth College, United States, has found that objects seen by a very bright electric spark are seen a second time, and sometimes a third and a fourth time, at an interval of about a quarter of a second. The subjective nature of this recurrent vision is shown

by the fact that if the object gazed at is kept moving, it nevertheless appears unchanged in place during the interval between the first or primary impression and the second or reflected one. It seems most probable that the second impression is due to the nerve-current of sensation being reflected back to the retina, and thence again to the optic ganglion.[1]

The nerve-current of Consciousness is excited chiefly, though not exclusively, by the commencement or cessation of that of Sensation. —We have seen that the secondary, or induced, electric current, is a momentary one, and flows when the primary current begins or ceases. It seems probable that the same is true of the nerve-current of consciousness. We know that consciousness is most forcibly excited, not by a continuing sensation, but by the commencement or cessation of a sensation;—we soon cease, for instance, to be conscious of a monotonous sound when it is not attended to, but we immediately become conscious of either its commencement or its cessation; and if a sound or any other sensation is very faint, it is always much easier to cognize it in the moment of commencing or ceasing than while continuing. The physiological ground of this fact is probably that a current in the nerves of consciousness is more powerfully excited by the commencement or cessation of a current in the nerves of sensation, than by the continuance of the same. Unlike the secondary electric current, however, the current in the nerves of consciousness continues to flow during the continuance of the current which excites it, though with diminished intensity when the exciting sensory current becomes monotonous. This is shown by the fact that such a sensation may be brought back into consciousness by attending to it.

Energy becoming static in electro-dynamic induction.—We have seen[2] that if two insulated wires are placed alongside of each other, and an electric current begins to flow along one, the molecules of the other are thrown into a state of tension, which

[1] The whole of Prof. Young's communication is given in Note A. at the end of this Chapter.

[2] See p. 494.

action appears as a momentary current; and when the current ceases to flow in the first wire, the molecular tension of the second is released, which action also appears as a momentary current. In the first of the two momentary currents, energy is taken up, and becomes static or potential; in the second, it again becomes actual.

Probable analogy to this in cerebral action.—It appears probable that there are facts of mental physiology somewhat analogous to these. Whatever affects the consciousness painfully is seldom felt as disturbing to the entire mental and bodily system, except so long as the shock to the consciousness is still felt; the most painful knowledge, or the intensest anxiety, ceases to be disturbing when it has become familiar. The laws of Habit are perhaps sufficient to account for this; but it is farther to be observed, that if news which has caused great sorrow is suddenly found to be untrue, or if a state of intense anxiety is suddenly ended, there is often a return of the same mental, and it may be bodily, agitation that marked the commencement of those states. It is perhaps not fanciful to suggest, that in the commencement of such a state some part of the cerebrum is thrown into a state of molecular or chemical tension, wherein energy is taken up and becomes static or potential; and that at its termination the tension is released, and the energy again becomes actual. This hypothesis agrees with the remarkable fact of the nervous agitation being alike at the beginning and at the end of the period of mental tension; the nerve-currents are similar, though reversed, just as the electric currents are similar, though reversed, in the experiment to which we have compared this. It appears probable that the place where energy is thus taken up and stored, is not the nerve-fibres but the ganglionic substance of the cerebrum, which, as already stated, is probably the seat of memory.

Nerves of Consciousness, Thought, and Will.—We have seen in a previous chapter[1] that the most accurate classification of the

[1] See pp. 478, 479.

mental functions appears to be into those developed out of sensation, which include Consciousness and Thought, and those developed out of the motor powers, whereof the highest is Will. The first of these, again, branches out into Feeling or Emotion, which is necessarily conscious; and Thought, which may be unconscious. When we regard the mental functions in their developed state, we may consequently enumerate them as Feeling, Thought, and Will. The anatomical structure of the brain supports this view, or at least is in harmony with it.

We have seen that the sensory ganglia are the seat of feeling and consciousness, and the cerebral hemispheres are the seat of thought. The nerves of consciousness we have seen to be probably those which connect the sensory ganglia with the ganglionic substance of the cerebrum; and it appears equally probable that the nerves which connect the various parts of the ganglionic substance of the cerebrum with each other are the nerves of thought.

Unconscious Thought.—The sensory ganglia are the seat of consciousness; the cerebral hemispheres are the seat of thought; and we may consequently conjecture, with great probability, that unconscious thought is due to nerve-currents flowing between various parts of the cerebral hemispheres, without entering the sensory ganglia. Owing to the remarkable power that nerve-currents have of setting one another in motion, currents in the nerves of thought generally start currents in the nerves of consciousness, and thought becomes conscious; but this is not always the case. Both sensation and thought are, I believe, in their own nature unconscious; and the nerve-currents of sensation and thought give rise to consciousness, not always, and not directly, but only by causing secondary currents to flow along the nerves of consciousness. As the consciousness of sensation is a distinct thing from the sensation itself, and there may be a sensation without the consciousness of it, so the consciousness of thought is a distinct thing from the thought itself, and there may be thought without the consciousness of it.

Recollection without apparent cause.—Of the existence of unconscious thought there is ample evidence, and it is now generally admitted by those who have studied psychology. To mention a single instance of this, probably the commonest, but by no means the most remarkable :—it is only by admitting that trains of thought, or suggestion, may go on in unconsciousness, that we can account for the mental phenomenon, which must often have come within every one's experience, of thoughts and memories coming suddenly into consciousness without anything whatever to suggest them, either in external circumstances, or in the thoughts that were consciously occupying the mind. I am myself very liable to this. Sometimes when my mind appears to be fully and consciously occupied; sometimes soon after awakening in the night, and when consciousness is perfectly awake but not occupied with any train of thought; I find recollections of places, of incidents, of lines of poetry, or of single words, coming into my consciousness. The things thus recalled are often uninteresting and trivial, and they often, I feel certain, have not been in my conscious memory for years. I have frequently, on their occurrence, sought for any possible link of conscious suggestion by which to account for them, and made myself certain that there was none.

In order, so far as it is possible, to complete the physiological theory of the mind which we are here attempting, it now only remains to speak of voluntary action, and the relation of the mind to motor action generally.

Ideo-motor action.—In many cases, remembered consciousness acts on the motor nerves, and on the whole organism, exactly as the original sensation, or the consciousness of it, would do. The thought of a disgusting object, for instance, sometimes produces nausea. Dr. Carpenter mentions an instance of sea-sickness being brought on by the sight of a ship tossing on a stormy sea. Such cases are to be regarded as cases of consensual action—due, however, to reproduced consciousness, not to sensation or the

original consciousness of sensation. Dr. Carpenter proposes to call these *ideo-motor* actions; indicating by this word that they are set going, not by a sensation, but by the revived consciousness, or idea, of a sensation. Ideo-motor action is thus related to ordinary consensual action, in the same way that recollection, or reproduced consciousness, is related to the original consciousness of a sensation.

Voluntary action. Nerves of Will.—Truly voluntary action is, however, distinct from ideo-motor, and probably depends on a different nervous action. We have endeavoured to show how there are two distinct sets of cerebral nerves, which may be respectively identified as the nerves of consciousness and the nerves of thought; and it seems probable that the nerves of will may also be identified. As already stated, it is believed that the pair of ganglia called the corpora striata constitute the nervous centre for consensual and voluntary motion. They are connected with the ganglionic substance of the cerebrum by thick strands of nerve-fibres, and all analogy is in favour of the belief that these are the nerves of will; just as the fibres that connect the sensory ganglia with the ganglionic substance of the cerebrum are the nerves of consciousness. We suppose, consequently, that when action is purely voluntary, the process is this: A current in the nerves of thought (which are not in direct connexion with either the sensory or the motor ganglia) determines a current in the nerves of will; and this acts on the motor ganglia, so as to determine muscular action, exactly as a current of sensation would do.

Summary.—Enumeration of mental functions.—The facts and theories concerning the organs of mental life, with their functions, may now be summarised; omitting the nervous organs of the insentient life; and omitting also the cerebellum, a nervous centre which appears to belong to the motor and instinctive life, though its functions are not clearly ascertained.

The various nervous actions belonging to sentient and mental life may be thus enumerated, in the order of their action one on the other :—

Sensation.
Consciousness (including Memory).
Thought.
Will.
Motor action.

Each of these is due to a current in its own special nerves, which current is produced by the mutual action of the nerve-fibres and the ganglia in connexion with them ; and a current in one set of nerves may excite a current in another set.

Diagrammatic statement of the organs of the mental life.—The mutual positions of the nerves and ganglia of the mental life may be represented in the following diagrammatic form, where the nerve-fibres are indicated by italics, and the organs which they connect by Roman letters :—

Ganglionic Substance of the Cerebrum.

Nerves of Thought.

Nerves of consciousness. *Nerves of Will.*

Sensory ganglia. Corpora striata, or ganglia of conscious and voluntary motion.

Sensory nerves. *Motor nerves.*

Organs of sense. Voluntary muscles.

Consensual action.—In consensual action the apparatus above the sensory and motor ganglia is not brought into play, and the several organs act on each other in the following order:—

Organs of sense.
Sensory nerves.
Sensory ganglia.
Corpora striata.
Motor nerves.
Voluntary muscles.

Ideo-motor action.—In ideo-motor action, the order is the following:—

Ganglionic substance of the cerebrum (where the memory, or idea, is registered).
Nerves of consciousness.
Sensory ganglia.
Corpora striata.
Motor nerves.
Voluntary muscles.

Voluntary action.—Consensual and ideo-motor action, it will be seen, differ in the origin of the impulse; in consensual action the impulse comes from below, in ideo-motor action from above; but they agree in its being communicated directly from the sensory to the motor ganglia, or corpora striata. In voluntary action, on the contrary, the impulse is communicated to the corpora striata by a special channel, as follows:—

Organs of sense.
Sensory nerves.
Sensory ganglia.
Nerves of consciousness.
Ganglionic substance of the cerebral hemispheres.—*Nerves of Thought.*
Nerves of Will.
Corpora striata.
Motor nerves.
Voluntary muscles.

We here suppose a sensory impression on consciousness to excite thought, and this to excite will; as when I see that the weather is fine, and consequently decide to go out. But the

thought may arise, as we say, spontaneously, that is to say without external or traceable cause; as when I decide to go out because I suddenly remember something that needs attention. In this case, the chain of causation is the same, only with the first four links left out; the action begins in the ganglionic substance of the cerebrum.

Somnambulism. Unconscious determinations of Will.—In ordinary mental states, the action of the nerves of will appears to be always accompanied with consciousness, but in somnambulism this is not the case. In somnambulism the action of the nerves of consciousness appears to be suspended, while the rest of the nerves of mind are at work. The actions of somnambulists show that their power of sense—of touch and the muscular sense at least, if not of sight—must be awake, and able to guide consensual action; thought and will are also active, and yet there is no consciousness. It may be said that what we have called voluntary action in somnambulism is really ideo-motor; but what I wish to insist on is, that in this state the determination to motor action comes from the cerebrum through a channel apart from consciousness, and most probably through the same nerves which in the normal state are the nerves of will, namely, those which connect the ganglionic substance of the cerebrum with the corpora striata.

Contrast of Somnambulism and Dreaming.—It has been well remarked that somnambulism and dreaming are the opposite of each other. In somnambulism, the motor powers are awake, and consciousness is asleep; in dreaming, consciousness is awake, and the motor powers are asleep.

Suspension of the power of one nerve to excite a current in another. Reverie.—The facts of somnambulism, and of less abnormal states, appear to show that, in particular cases, the different sets of nerves which we have described, lose, in a great degree, the power of exciting currents in each other. The

physical change whereon this depends is probably rather in the ganglionic masses than in the fibres, and may perhaps consist merely in a lowered capacity for action due to an anæmic or bloodless state. Thus, in somnambulism the motor actions do not excite consciousness, as they normally would do; and in a nightmare dream there is often a strong consciousness of terror, and a wish to escape from some imagined danger, yet the motor nerves do not stimulate the muscles to act. There appears to be something analogous to this in reverie; in that state consciousness may be fully occupied with materials furnished by memory or imagination, while it is asleep to what the eye is seeing or what the hand is doing. In physiological language, the currents of sensation that reach the sensory ganglia excite in the nerves of consciousness no currents strong enough to be reflected downwards from the ganglionic substance of the cerebrum, and so to produce consciousness.[1]

Nervous mechanism of Attention.—We go on to make some suggestions as to the nervous mechanism of attention and of the voluntary direction of thought.

We have already seen that where sensation first appears in the lower ranks of the animal kingdom, there seems to be no mental life; sensation is only a guide to muscular action. It is also known that when any muscular action is capable of being exerted without the intervention of sensation or consciousness, the intervention of sensation or consciousness tends to make it not more but less energetic;—thus, for instance, when sensation in the lower extremities is destroyed by an injury to the spinal cord, the patient, on the soles of his feet being tickled, kicks more forcibly than he would in the normal state, though without any consciousness of doing so. This is only one instance of a general law, which is verified by experiments on animals. The reason of this fact appears to be, that when communication between the spinal cord and the brain is cut off, the entire energy due to the nervous current which is

[1] See p. 503 *et seq.*

exeited by any such impression as tiekling the fect, is cxpended in exciting the appropriate muscular responsc ; but when the communieation is open, a part of the eurrent is eondueted upwards to the sensory ganglia, where, unless it is very weak, it excites currents in the nerves of conseiousness. Although, as we have already stated,[1] a seeondary eurrent is not supplied with energy by the primary whieh exeites it, yet the aetion appears to be so far quantitative that the primary current eannot exeite two secondaries with as much energy as it ean exeite one ;—thus, a current of sensation ean excite either a motor current or a eurrent of conseiousness separately, with greater foree than it ean excite both. This may be due merely to the obvious fact, that the nervous energy of the entire organism is a limited quantity, and if a sensible quantity of it is expended in one direetion, there is the less left for expenditure in other direetions. It is well known, for instanee, that bodily exereise diminishes mental exeitement; and conversely, that whatever absorbs the attention tends to eause relaxation of the museles; as when some surprising pieee of news makes one involuntarily pause in walking or eating.

When the muscular response due to a sensation takes plaee immediately, thc peeuliar state of excitement and strain whieh is ealled attention does not arisc. But when the museular response is delaycd or hindered, the sensory eurrent, or part of it, whieh would othcrwise have been employed in exeiting the museular response, is employed in exeiting conseiousncss. This takes plaee in the act of attention.

But this is not a full aeeount of the matter; for, what is it that dclays or hinders the museular responsc? I would suggest that attention arises when an inhibitory impulse eomcs from the eerebrum, probably through what wc havc cndeavoured to identify as thc nerves of will, opposing and restraining the motor impulse which is thc immediate responsc to a sensation.

The action of a Dog in pointing.—Watch a dog pointing; you

[1] See pp. 495, 496.

will see that his stillness is not that of rest, but of strain, as if between two evenly balanced impulses, the one impelling forward and the other holding back. Darwin suggests that the pointing of a dog is only the exaggeration of the pause of a carnivorous animal going to rush on its prey; and he adds that probably no one would have thought of teaching a dog to point unless he had noticed such a tendency. But whatever may be the origin of this remarkable habit, the muscular tension that can be seen, and the mental tension that may be inferred, show an opposition between the merely consensual impulse to rush on the prey when seen, and a mental determination to hold back. The act of pointing may not now be accompanied with this mental conflict and strain, but it has probably so originated.

Now, this is a type of attention;—which may be defined as a state of mental, and frequently also of muscular, strain due to an action of the will which is called forth by a sensory impression whereto there is no motor response. We conclude therefore that the act of attention is originally due to an impulse originating in the cerebrum, and conveyed through the nerves of will to the motor nerves, opposing and restraining the ordinary motor response that would be spontaneously made to a sensory impression. The nerve-current due to the sensory impression is thus hindered from discharging itself in exciting the spontaneous or consensual motor impulse, and consequently has a greater effect in exciting a current in the nerves of consciousness than if it were permitted to produce its normal effect. Hence the heightening of consciousness which occurs in the act of attention.

This is what we conceive to be an account of the simplest and most elementary form of attention; but that power in Man, though perhaps never in animals, is ultimately developed into the power of directing and controlling thought at will; and in that development, it ceases to have any direct connexion with the motor system.[1]

[1] The foregoing remarks on Attention have been suggested by Mr. Sully's Review of Wundt's *Physiological Psychology* in *Mind*, January, 1876.

In the present chapter, we have considered the organic structures whereon mental action appears to depend. In the next, we shall have to consider the deepest and most fundamental questions regarding the relation of the mental to the organic nature.

NOTES.

NOTE A.

RECURRENT VISION, BY PROFESSOR C. A. YOUNG.[1]

From the *American Journal of Science and Art* for April, 1872, as reprinted in *Nature* of the 25th of that month.

"In the course of some experiments with a new double plate Holtz machine belonging to the college, I have come upon a very curious phenomenon, which I do not remember ever to have seen noticed. The machine gives easily intense Leyden-jar sparks from seven to nine inches in length, and of most dazzling brilliance. When, in a darkened room, the eye is screened from the direct light of the spark, the illumination produced is sufficient to render everything in the apartment perfectly visible; and what is remarkable, every conspicuous object is seen *twice* at least with an interval of a trifle less than one quarter of a second—the first time vividly, the second time faintly; often it is seen a third, and sometimes, but only with great difficulty, even a fourth time. The appearance is precisely as if the object had been suddenly illuminated by a light at first bright, but rapidly fading to extinction, and as if, while the illumination lasted, the observer were winking as fast as possible.

"I see it best by setting up in front of the machine, at a distance of eight or ten feet, a white screen having upon it a black cross, with arms about three feet long and one foot wide, made of strips of cambric. That the phenomenon is really subjective, and not due to a succession of sparks, is easily shown by swinging the screen from side to side. The black cross, at all the periods of visibility, occupies the same place, and is apparently stationary. The same is true of a stroboscopic disc in rapid revolution; it is seen several times by each spark, but each time in the same position. There is no apparent multiplication of a moving object of any sort.

"The interval between the successive instants of visibility was measured roughly as follows:—A tuning-fork, making 92½ vibrations per second, was adjusted, so as to record its motion upon the smoked surface of a revolving

[1] See p. 506.

cylinder, and an electro-magnet was so arranged as to record any motion of its armature upon the trace of the fork ; a key connected with this magnet was in the hands of the observer. An assistant turned the machine slowly, so as to produce a spark once in two or three seconds, while the observer manipulated the key.

"In my own case the mean of a dozen experiments gave 0·22 of a second as the interval between the first and second seeing of the cross upon the screen ; separate results varying from 0·17 to 0·30. Another observer found 0·24 as a result of a similar series.

"Whatever the true explanation may turn out to be, the phenomenon at least suggests the idea of a *reflection of the nervous impulse* at the nerve extremities, as if the intense impression upon the retina, after being the first time propagated to the brain, were there reflected, returned to the retina, and from the retina travelling again to the brain, renewed the sensation. I have ventured to call the phenomenon 'Recurrent vision.'

"It may be seen, with some difficulty, by the help of an induction coil and Leyden jar, or even by simply charging a Leyden jar with an old-fashioned electrical machine, and discharging it in a darkened room. The spark must be at least an inch in length."

NOTE B.

LOCALISATION OF FUNCTIONS IN THE BRAIN.

Inconclusiveness of Dr. Ferrier's experiments. Lewes and Maudsley.—In the foregoing chapter I have made no reference to those remarkable experiments whereby Dr. Ferrier has endeavoured to throw light on the localisation of functions in the cerebrum, because I do not think any one is yet able to show what we are really to infer from them as to the functions of its different parts. What the experiments directly show, is that stimulation of particular parts of the cerebrum has the effect of convulsing particular groups of muscles ; and this is certainly not sufficient to prove that its external convolutions constitute a congeries of motor ganglia. As Mr. Lewes has remarked : "We do not consider the fauces to be the [motor nervous] centre of vomiting, although tickling the fauces will be followed by retching ; we do not consider the centre of laughter to be located in the sole of the foot because tickling the sole causes laughter."[1] It is possible, and probable, that the corpora

[1] See Mr. Lewes's notice of Dr. Ferrier's "Functions of the Brain," in *Nature* of 23rd and 30th November, 1876.

striata are really the nervous centres for the motion of the voluntary muscles, and that when particular muscles are convulsed by irritating particular convolutions of the cerebrum, the effect is not produced directly but through the corpora striata, just as laughter is caused by tickling the sole of the foot, not directly but through the brain. Dr. Maudsley says[1] :—

"These experiments are quite in accordance with the opinion that the actual co-ordination of movements is effected in the motor ganglia, and with the observed phenomena of sensori-motor [or consensual] action, but they are also consistent with the theory that there are in the cortical [or ganglionic] layers [of the cerebrum] higher centres, which are differentiated by their special connexions with the co-ordinating centres below, and minister to voluntary movements, which supply us with the mental presentations, so to speak, of the movements."

[1] *Physiology of Mind*, p. 266

CHAPTER XXXII.

AUTOMATISM.

Definition.—An automaton is defined as something which can only act as it is acted on. The meaning of the word is at variance with its etymology, but this need not mislead us.

All Vegetable and much Animal life are automatic.—All machines are automata; and all living beings are so, at least in part. It needs no proof that vegetable life is automatic; and the same is true of a great part of the animal life, or motor activity, of all animals whatever, and of the entire animal life of the lowest. We can scarcely doubt that such actions as that of a sea-anemone in seizing on its prey with its tentacles, or in closing itself when left uncovered by the receding tide, are as purely automatic, that is to say as completely independent of sensation, consciousness, or will, as the action of the heart in Man. But, as we have argued in the preceding chapters, though independent of consciousness, they are not independent of Intelligence; they are instinctive, and instinct is intelligence unconscious of itself.

Automatic motions of Plants.—There are vegetables also which perform motions that appear not to differ in any character from those of the lowest animals. There is probably no difference whatever between the action of the tentacles of a sea-anemone in seizing its prey, and that of the leaves of carnivorous plants like *Drosera* and *Dionæa*, which crush insects to death and suck

their juices; nor between the sea-anemone in closing when the tide leaves it uncovered, and the daisy in closing at sunset. The revolving motion of the tendrils of such plants as the Virginian creeper, in seeking a support,[1] is of the same kind.

Primary Automatism is due to vital Intelligence.—Actions like these, which have no relation to consciousness, are defined as primarily automatic. There is every reason to believe that such instincts as the cell-building instinct of the bee are of the same class. We cannot tell how far the bee has a consciousness of what it is doing, but it certainly has not any knowledge of those geometrical properties which make the hexagon the most advantageous form for economizing wax. It has been argued in the foregoing chapters that neither habit, nor natural selection, nor any other unintelligent agency, can account for the origin of such instincts as these. Primarily automatic actions, then, may be defined as those automatic actions which are the direct results of vital Intelligence.

Secondary Automatism.—But there are other actions which are secondarily automatic; that is to say, actions which were not automatic orginally, but have become so. To this class belong all actions which, as the result of education, have come to be performed by unconscious habit. Thus, many persons are able to read aloud accurately from a printed book, without attending to the meaning of the words, and while thinking of something else; and it is also possible to perform a piece of music which has been thoroughly learned while the entire attention is engrossed with conversing on some other subject. But perhaps the most wonderful case of secondary automatism on record is that mentioned by Mr. Lewes,[2] on the authority of Trousseau, of "an epileptic patient of his who was occasionally seized with attacks of complete unconsciousness while he was performing in the orchestra; yet on re-awakening to consciousness, he

[1] See p. 89.
[2] *The Physical Basis of Mind*, p. 197, note.

found that he had continued to play, had kept proper time, and played the proper notes."

Habit is second nature.—Such action as this is consensual;—we have endeavoured to give its physical explanation in the foregoing chapter. When the power of acquired habit becomes so complete that it can be exerted independently of any effort of attention, it so nearly resembles primary instinct, that, as the proverb says, habit has become a second nature.

Nature is more than first habit.—It has also been said that nature is first habit; but if the reasoning of the present work is sound, this is only a half-truth, and is untrue if understood absolutely. There are natural tendencies which are antecedent, in the order of causation, to any formation of habits. To say that habit is, or may become, a second nature, is a proverbial way of saying that actions may, by force of habit, come to be secondarily automatic; no one doubts this; but the converse proposition, that nature is first habit, if understood absolutely, would assert that no instinct is anything more than a habit which was originally acquired as such, but has become hereditary; and consequently, that actions which are now primarily automatic were only secondarily so in former generations. In speaking of the bee and the ant,[1] we have endeavoured to prove that this is not always so. Their instincts, which are the most wonderful known, were primarily automatic from the first.

Hereditary habit. Dogs. The Sea-lion.—Beyond doubt, however, this is not true of all instincts. There are some, and probably many, actions which have become primarily or congenitally automatic for the individual, though they are only secondarily so for the race. We may instance the hereditary habits, or acquired instincts, of the pointer and the sheep-dog;—a young pointer will often point the first time he is taken out, and the sheep-dog, as we have previously mentioned, is born

[1] See p. 416.

with a tendency to run round a flock of sheep instead of at them. The same is possible in wild races. It is stated that the young sea-lion (a species of seal), will not enter the water till forced to do so by its dam, and then does so with the utmost reluctance.[1] This suggests that swimming must be not a primary but an acquired power in the species; and the same inference is to be drawn from the facts of classification, which make it almost certain that the ancestral form of all the Mammalia—of the common or placental Mammalia at least—must have been a land animal; though the seal, and some other genera of the class, besides the entire order of the Cetacea or Whales, have become aquatic. In the sea-lion, the acquired automatism is less complete than in the pointer and the sheep-dog.

There is no criterion for distinguishing secondary from primary Automatism.—There is not always any certain criterion whereby we can tell whether an instinct was really primary in the race, or has become so secondarily through the effect of hereditary habit. In the case of the sea-lion, we have seen that the habit of swimming appears to be secondary. In Fishes, on the contrary, it is most likely primary, for we have reason to believe that all the ancestors of the class, back to the first little mass of vitalized jelly, have been inhabitants of the water. This however does not prove anything as to the question whether primary automatism exists, in the sense in which I have defined it; namely as the result of unconscious Intelligence acting without habit, or in anticipation of it.

Bain's Theory of the Will.—There are instances which prove that it is possible for the same action to be primarily automatic in one species and secondarily so in another. Thus, the habit of walking becomes secondarily automatic in the human species, in the act of learning to walk; but in the horse it is primarily so, for the foal is able to walk as soon as it is born. It has

[1] See the Report of Mr. J. W. Clark's lecture at the Zoological Gardens, in *Nature*, 29th April, 1875.

been maintained by Professor Bain, in an elaborate disquisition, that many of the actions of lambs and other young animals, such as moving about and sucking, which appear to be instinctive, that is to say primarily or congenitally automatic, are in reality secondarily so; and that their apparently primary character is due to the great rapidity with which habits are formed in the earliest period of life. On this he bases what he calls his theory of the will; which, if I understand it, consists merely in this, that the will is developed out of the primary impulse to seek pleasure and to avoid pain.

Instinct is primary Automatism: Habit is secondary Automatism.—But I do not believe that Bain's interpretation of the facts concerning the actions of young animals can be sustained. Mr. Spalding's experiments on the perceptive and motor powers of newly-hatched chickens prove that these are truly congenital; that is to say they pick up food, and run towards the hen when called, without having to learn how to do so. But even if Bain's theory could be sustained, and with all the help it could receive from the doctrine of hereditary habit, it still would throw but little light on the mysterious and wonderful facts of instinct; for, as we have seen, it is a fact which cannot be explained away, that actions, which by every criterion are truly instinctive, are performed by vegetables, and by animals which are too low in the scale to be endowed with consciousness.[1] And there is not the slightest doubt that primary automatism, or instinct, and secondary automatism, or habit, graduate into each other, and are often indistinguishable.

Is there any fundamental distinction?—Is there, then, any absolute and fundamental distinction between primary and secondary automatism?

It is to be sought only in their relation to Consciousness.—We reply that there is no absolute distinction between unintelligent

[1] See p. 521.

and intelligent actions. Habit and Intelligence co-operate in every function of the motor and nervous life, from the blindest instinct up to the most intelligent exercise of conscious will; and, as has been maintained in the foregoing chapters, in the vegetable life also. The distinction between primary and secondary automatism belongs to their relation, not to Intelligence, but to Consciousness. This question opens the entire subject of the relation of Action to Feeling; and, consequently, the subject of Automatism.

The motive power of human action. Stoics and Epicureans.—Long before any one had dreamed of a physiological basis for the science of Mind, the question was debated in the schools of Greek philosophy, What is the motive power of human action? The reply of the Stoics was, The desire of self-preservation; that of the Epicureans, The desire of happiness (or pleasure), and the fear of pain.[1]

Self-preservation and the impulse to Pleasure are not the same.—It may be thought that these two replies come to the same thing; but facts taken from the opposite ends of the animal scale will show that this is by no means the case. The sea-anemone, in closing when the tide leaves it uncovered, is actuated by an impulse to self-preservation; but there can be no impulse to avoid pain in a being which has no more sense of pain or pleasure than a daisy. And in Man, consciousness generally affirms that the love of life is more than a mere resultant from the desire of the pleasures which life contains, and is stronger than such a resultant would be.

Both are influential.—From the sea-anemone up to Man, then, the impulse to self-preservation is primary, and the reply of the Stoics is at least partly true. I maintain however that the reply of the Epicureans is partly true also. The desire, or rather the impulse, of self-preservation, corresponds to the domain of

[1] I make this statement on the authority of one of Arthur Hallam's Essays.

instinct, or primary automatism;—the desire of pleasure and the fear of pain correspond to the domain of voluntary action and secondary automatism.

They generally but not always coincide.—It is true that in normal cases these two impulses coincide;—the impulse to self-preservation normally coincides with the impulse to seek pleasure and to avoid pain. In other words, the pleasure-seeking instinct is generally guided aright by vital intelligence; though, as we have already remarked, there are exceptions to this law.[1]

Self-preservation includes that of the race.—It must be remembered that when we speak of self-preservation from the point of view of general biology, we include the preservation and perpetuation of the race, and consequently the reproductive and maternal instincts.

Instinct comes under the law of Adaptation.—Through the effect of habit and natural selection, every living race constantly tends to become adapted to the external conditions of its existence; but this adaptation is perhaps never quite perfect. The unconscious intinctive tendency to self-preservation—in other words, to perform such actions as tend to the welfare of the organism—is a part of this adaptation; and the same adaptation is effected consciously when animals become sentient and conscious, and pursue their welfare no longer from a mere blind instinct, but from the impulse to seek pleasure and to avoid pain.

The Automatist theory stated.—In many cases, however, and those the simplest, the impulse of self-preservation, and the impulse to avoid pain, not only coincide but are identical. In a case which, in my country at least, has become proverbial, namely that of "dropping a hot potato," the action belongs to both classes. A simple and elementary instance like this is the

[1] See p. 462.

best on which to raise the question of automatism;—and the question is really this—What is the relation of sensation to action? Is sensation a link in the chain of causation, as men generally and naturally believe?—or is it, as the theory of automatism maintains, only a sign of nervous action without being in any true sense a cause? When a man feels that a potato is unpleasantly hot and drops it, is the feeling of pain the *cause* of the nervous action which determines the muscles to open the fingers? or is it only a *sign* of nervous action determining muscular action, which might equally well go on in unconsciousness? The latter is the reply given by the automatist theory, which may be briefly stated thus:—that feeling, or mental action, is always the effect of nervous action, and never its cause; that consciousness never enters into the chain of causation; and that the real causes are currents of nervous energy, whereof feeling and will are only signs.

Reply to the common-sense objection to Automatism.—The automatist theory is so contrary to common sense, that this alone will ensure its rejection with most men. But the dictum of unanalysed common sense is never altogether conclusive on a speculative question; and the reply of the automatist to the appeal to mere common sense is something like this:—"The belief that the will of Man or of any other animal can influence matter, is only the last survival of the savage philosophy of Fetichism or Animism, which taught that every thing that showed powers of life or motion did so in consequence of an indwelling soul. The time was, when it would have appeared an insult no less to common sense than to religious reverence, to say that the sun and the stars are nothing but vast fires, and that the moon and the planets move in virtue of no other forces than those which determine the path of a stone when it is flung from the hand; and the time will be, when it will be as impossible to doubt that the will is a mere resultant from the laws of nervous energy, as it is now to doubt that the celestial motions are absolutely determined by the laws of force."

It will be observed that the foregoing is a statement, not of my own position, but of the automatist position, to which I am opposed.

Common sense is wrong as to the origin of muscular energy.—It is true that unanalysed common sense is demonstrably misleading as to one part of this question. When we are conscious of exerting muscular energy by an effort of the will, it is natural to believe that the energy so exerted is called into existence by the will at the moment;—yet such is not the fact; the energy was previously latent in the organism, and is not produced in muscular action, but only transformed; just as the motor energy of a steam-engine is not produced by the engine, but only transformed from its previous state of existence as heat.[1]

Relation of consciousness to nervous action.—It is also as certain as the nature of the case admits of, that sensation and mental action are never independent of nervous action; and in all nervous action a transformation of energy takes place. In other words, every feeling, every thought, and every voluntary determination, is accompanied, *whether as cause or effect*, by a current of nervous energy. And it is equally certain that the character of nervous action is physically and physiologically the same, whether it is accompanied by consciousness or not.

Strength of the argument for Automatism.—In view of these three facts, namely, that the organism cannot create and can only transform energy; that consciousness is never independent of nervous action; and that consciousness does not change the character of nervous action—it appears that in such a case as that of dropping a hot potato, where action follows immediately on sensation without any intermediate link of thought or voluntary determination, the automatic theory is, I do not say established, but at least defensible. That is to say, it may be

[1] See the Chapter on "The Dynamics of Life" (Chapter II.).

maintained—not plausibly perhaps, yet without absurdity—that, in the case mentioned, the feeling of pain from heat is not a necessary link, nor a link at all, in the chain of causation.

Reflex action.—The chief argument in favour of this view is the fact, that muscular actions which normally follow sensation and appear to be its effect, may under abnormal circumstances be the effect of stimuli which do not produce sensation; as in the well-known and very remarkable case of the convulsive motions which are caused by tickling the feet, being equally produced when an injury to the spinal cord prevents any impression on the nerves from being conducted upwards to the sensory ganglia, and there producing an impression on the consciousness. It may be maintained—and, if I understand his meaning, Mr. Lewes did maintain it in his *Physiology*—that in such a case as this there really is sensation; and that what feels the tickling is not the man, the centre of whose life is in the brain, but the animal which is cut off from the man by the injury to the spinal cord, and has the centre of its life in the spinal cord below the injured part. This strange conjecture cannot be disproved; but the automatic motions of some vegetables, to which we have referred already, prove that the power of performing motions in response to a stimulus, does not involve any necessity whatever for sensation. There appears however to be an intermediate kind of action between the voluntary and the merely reflex; namely that which Dr. Carpenter calls consensual;—wherein the sensation is really felt in the sensory ganglia and guides action, but without exciting consciousness, as in the case of the epileptic patient who was able, while in an unconscious state, to play on his musical instrument with perfect accuracy.

Felt and unfelt stimuli.—According to the automatic theory, then, there is no difference between motion excited by a felt stimulus and motion excited by an unfelt one, except that in the latter case sensation is absent, while in the former it is

present as a mere accessory, not influencing the effect. The difference is no greater than that between two clocks which show the same time, while one of them strikes the hours and the other does not; the sound of the striker is an important and conspicuous effect of the motions of the clock, but it does not influence the motions; and according to the automatic theory, the idea that the muscular action which responds to the stimulus is caused by the sensation itself, rather than by the nervous action whereof the sensation is merely the sign, is the same kind of error as if a savage were to fancy that the striking of a clock was the voice of a spirit commanding it to go on. If there were no such thing as mental action transcending mere bodily sensation, perhaps the reasoning that leads to this conclusion would appear unanswerable.

In such cases the automatism is primary.—It may be maintained that when the foot is withdrawn under the stimulus of tickling, though the stimulus is unfelt by reason of a wound in the spinal cord, the case is one, not of primary, but of secondary automatism; and that the nervous system responds to the unfelt stimulus, only because it has learned to respond to a felt stimulus. This would perhaps be plausible if we had no facts except those presented by Man and the higher animals. But the comparative study of nervous and muscular action in the higher and in the lower animals, and the doctrine of Evolution generally, show that actions, such as dropping a hot potato, which are independent of the will though apparently dependent on sensation, are as a general rule truly instinctive;—that is to say not secondarily, but primarily automatic;—and have not been developed out of voluntary action, but out of unconscious organic action. In other words, the conscious life has been developed out of the unconscious life, and not the converse.

The automatic theory applied to Mind.—The automatic theory, however, maintains that not in consensual or instinctive action

only, but also when action is in the highest sense voluntary, nervous and muscular action go on as if in unconsciousness, and the conscious will does not become a cause, but is only a sign, of the nervous action which is the true cause of motion. And not only so, but, according to the same theory, this is equally true of mental action. When thoughts succeed each other, one thought is not really the cause of another; the relation of cause and effect is between nervous currents, which, as we know, have the power of exciting each other; and the conscious element in thought has no more to do in producing thought, than has the sound of a clock in striking with producing the motion of the machinery.

Greatness of the paradox.—Mere common sense will probably reply that this is contradicted by consciousness, and must be untrue.

Such a reply is seldom conclusive, and it may be utterly misleading, as in the case of the earth's motion, which seems to be contradicted by our consciousness of being at rest. But it is well to show how enormous is the paradox involved in the automatic theory. If that theory is true—if consciousness is mere surplusage, and is never a cause, but only a sign, of action—it follows that all human history might have gone on in unconsciousness; the building up of kingdoms and republics, the development of art, of science, and of faith, might just as well have gone on, or rather appeared to go on, with unconscious puppets for actors instead of men, without a throb of pain or a glow of pleasure; wars might have been fought without ambition, pictures painted without a sense of beauty, music composed and performed without a love of harmony, and prayer uttered without hope or fear, —all as the result of nervous action never translating itself into consciousness. If the theory of Automatism is true, it follows that

"Man, who seemed so fair,
Such splendid purpose in his eyes,

> Who rolled the psalm to wintry skies,
> Who built him fanes of fruitless prayer,

(fruitless indeed !)

> Who loved, who suffered countless ills,
> Who battled for the true, the just," [1]

—that Man is but a conscious automaton, and might without violation of any law of causation have been an unconscious one.

But not only this. If Automatism is true, and if feeling has no influence on action, what is the relation of action to feeling? It is the fundamental datum of any possible theory on the subject, that when organisms become sentient, healthy action is accompanied by pleasurable feeling. In addition to this, we naturally believe that the hope of pleasure and the fear of pain guide the actions of organisms into healthy and beneficial channels of action; and it is the purpose of the present chapter to show that this spontaneous belief is scientifically true. If this belief is false, and if consciousness has no power to guide action, what is the meaning of the connexion of healthy action with pleasure, and the opposite? and what is the meaning of the apparent guiding power of hope and fear? If our spontaneous belief is true, the connexion between the hope of food or the fear of being eaten, and the actions appropriate thereto, is as obvious and as intelligible as the connexion between the premises of a demonstration and its conclusion. But were the automatic theory true, and were the connexion in question not one of causation, it would no longer be an intelligible connexion. In that case, this relation might have been reversed throughout, without any law of causation being violated; so that healthful actions should have been accompanied with pain and destructive ones with pleasure; and organisms should have been impelled by vital instinct to seek pain and to avoid pleasure. If Automatism were true, I say, such a connexion between feeling and action would have been as natural and as intelligible as that which actually exists.

[1] Tennyson's *In Memoriam.*

This appears to be a perfect *reductio ad absurdum* of Automatism. But it may be said that beyond the domain of abstract logic and mathematics, a *reductio ad absurdum* is seldom satisfactory; and we go on to a more direct argument.

When muscular action is directed by Will, the links of causation are not all within Consciousness.—We have here to consider the relation of the will to the muscles. Consciousness tells nothing about the manner or the causal agency of the production of voluntary muscular action. In the act of writing, I am conscious of the mental determination to move my fingers, and of the motion of my fingers; but between these is an intermediate link which is hidden from consciousness; namely, the nervous current from the brain, along the motor nerves of the arm to the muscles of the fingers; we know nothing of this by direct consciousness; all that we know, or can know, about it, is a result of anatomical and physiological research. The relation between the voluntary determination to move the fingers, and their motion, is thus outside of consciousness; and it does not absolutely contradict consciousness, to assert that such relation is not causal; that all causation in the nervous and muscular systems is independent of consciousness; and that the belief in the power of the will to act on matter, though natural and all but universal, is altogether false.

Mental action where all the links of Causation are within Consciousness.—But it is quite different when the same is maintained of purely mental action, whereof all the links of causation are within the sphere of consciousness. When will determines thought, or when thought determines thought, or when thought determines feeling, the relation between cause and effect is within the sphere of consciousness; and to deny the relation of cause and effect in these cases, is to contradict one of the clearest and most elementary dicta of consciousness. For instance;—if, by a voluntary effort I direct my thoughts to some particular

question, this is causation of thought by will;—if a new argument occurs to me which I accept as a solution of a previously felt difficulty, this is causation of thought by thought;—if I feel pleasure at the clearing up of the difficulty, this is causation of feeling by thought. The causal relation is here not matter of inference but of immediate knowledge, arising in consciousness; and it cannot be explained away by any result of inference or argument based on data of a different kind. This is a reply to the automatic theory, and a reason for believing in the distinct agency of Mind, which appears to be scientifically compelte.

It is by these that Causation comes to be known.—I will remark here, though it may not be quite relevant, that it is these relations of causation made known by immediate consciousness which, in my opinion, constitute the basis of our conception of causation. We learn the fact of causation by becoming conscious of our own mental action. We have spoken on this subject in Chapter XXVII.

Automatic mental activity.—It is, however, to be admitted that mental action is often independent of the will. When this independence is complete, the mental state is called reverie.

Automatism denies the action of the mind on the body. It clears up no mystery.—The mental action of body and mind has always been regarded as a great mystery. Automatism does not profess to throw any new light on the action of the body on the mind; and the action of the mind on the body is not explained by Automatism, but denied. Were this theory established, although the subject of the relation between body and mind would in one sense no doubt be simplified, in that it could be described in simpler propositions, yet no mystery would be in the slightest degree cleared up. The fundamental and inexplicable mystery is that consciousness should arise at all, and should be influenced by material agencies. But when consciousness is an effect, there is no additional mystery in its becoming, in its turn, a cause;—

when consciousness is influenced by matter, there is no additional mystery in its being able (under the name of Will) to influence matter. On the contrary, physical analogies lead us to expect that it should be so. This must be further explained.

Physical analogies opposed to automatism.—Action and reaction are equal and contrary; and from this it follows that when cause and effect exchange places, the direction of the action is reversed.

Electro-dynamics. Lenz's law.—One of the best instances of this is the law of electro-dynamic action known as Lenz's law. The simplest, though not the most general, statement of that law is as follows:—

If a conducting wire is moved in the neighbourhood of a magnet so as to cut through the lines of magnetic force, an electric current will be produced in the wire; and conversely, if an electric current from an external source is sent through the wire, it will tend to move the wire; but the motion which is produced by the current is in the opposite direction to the motion which would produce the same current.

This law was first proved experimentally, but when the general properties of magnets and electric currents are known, it is seen to be deducible from the law that action and reaction are equal and contrary.

Similar law in thermo-electricity.—Another illustration of the same general principle is somewhat similar to this, though, so far as I am aware, it could not have been deduced from elementary principles with our present knowledge of the intimate nature of electric action. If a joint connecting two metals that conduct heat unequally is heated, an electric current is produced. If a current from an external source is sent through the joint in the same direction as that of the current which would be produced by its heating, the joint will be cooled below the surrounding temperature.

Heating of india-rubber.—Electricity is a polar force, but the same principle applies to forces which are not polar. Thus, when india-rubber is stretched, so as to lengthen it out, it heats; and conversely, if a string of india-rubber with a weight attached to it is heated, it shortens.

Analogy to these in the action of consciousness.—In these three instances, we see that an effect may become in its turn a cause; and that when this is so, the direction of the action is reversed. So, we maintain, it is with consciousness. Sensation is an effect of currents from the external terminations of the nerves up the nerve-trunks to the brain; and we maintain that sensation and consciousness are in their turn the cause of currents from the brain down the nerve-trunks to the motor nerves, determining muscular action.

Objection to the analogy from the unique character of consciousness.—It may be said in reply to this, that in the instance mentioned from physical science the effect is of the same kind as the cause, but in the case now under discussion, the effect, namely consciousness, is altogether unique and totally unlike any physical phenomenon.

Reply.—The reply to this is twofold. In so far as consciousness is sufficiently kindred with the merely physical forces to be acted on by them, it is sufficiently kindred with them to act on them. In so far as consciousness is a unique and unparalleled phenomenon, this is a reason, not for thinking that it can be without effect, as Automatism teaches, but rather for expecting it to be accompanied and followed by other wonderful actions and properties:—and we maintain that it is so accompanied and followed by Will and Freedom.

Objection from the conservation of energy. Reply, that Will does not create but directs energy.—It has been said that the law of the conservation of energy makes it impossible for the Will to

act on matter, and thus proves Automatism to be true. The objection would be valid were it contended that consciousness or Will could create energy. But we know this is not the case. Energy cannot be created by any power whatever, whether conscious or unconscious, except by Him who originally called the universe of matter and energy into existence. But though the Will cannot create energy, we contend that it can direct motion.

The modus operandi is mysterious.—But how can the Will direct motion? How can motion be directed by that which is confessed not to be a force—that is to say, not to have the power of producing or putting forth energy in even the most infinitesimal quantity?

This question must remain for ever unanswered. We cannot tell how the Will directs energy and thus influences matter. But neither can we tell how a physical change can produce sensation and influence consciousness. The two mysteries are alike and parallel; and if we admit the one, as we must, there is no additional difficulty in admitting the other.

Physical instances showing its possibility.—It is enough if we can show that it is possible for motion to be directed by a cause which can neither add to nor subtract from the quantity of the energy due to the motion; and there are many physical illustrations which show the possibility of this, though we must admit that they do not suggest anything as to what the real action of the Will probably is. If a ball is rolling along a frictionless but curved tube, the direction of its motion varies from moment to moment, while the energy due to its motion remains unchanged; and the same is true of a ball which is twirled in a circular orbit by a perfectly unyielding string.

It may be said that no tube is perfectly frictionless, and no string perfectly unyielding; and that if these conditions are not fulfilled, some transformation of energy will take place.

I reply, firstly, that we have to do with the laws of abstract dynamics, which leave such imperfections of material out of

account; and secondly, that although the laws, or assumptions, of abstract dynamics cannot be perfectly realized under experimental conditions, yet they are absolutely true, and are perfectly realized in molecular actions. The molecules of gases are constantly striking against each other and having the direction of their motions altered without any loss of energy.

Strength of Will is distinct from strength of Impulse. Effect of Intoxicants.—If the theory of Automatism is true, the Will is only the general resultant of all the mental forces. We maintain, on the contrary, that it is more than this. One of the most remarkable proofs of the distinctness of the Will from the lower and automatic powers of the mind, is the fact mentioned by Dr. Carpenter,[1] that intoxicants, especially alchohol, opium, and haschisch, exalt the automatic activity of the mind, stimulating the spontaneous flow of thought and imagination and heightening the vividness of the feelings, while they weaken the Will. But this is only a striking experimental proof of what is quite well known independently. It is one of the most important of all truths in either psychology or ethics, that strength of will, or of character, is a totally distinct thing from strength of mere impulse or passion. Strength of impulse is compatible with weakness of will, because strength of will implies power of self-control. On any automatic or mechanical theory of mind, this appears impossible and self-contradictory. It sounds like a merely identical proposition to say that in every conflict of motives the strongest impulse is that which prevails. Yet every one who has ever performed any act of true self-control or self-denial, knows that such is not a substantially true account of the case; and that it is possible for Will, directed by conscience or the sense of duty, to prevail over mere impulse. The fact that self-denial and self-renunciation are possible, shows that human motives cannot be all resolved into the fear of pain and the love of pleasure;—the fact that men have died

[1] *Mental Physiology*, p. 636.

as martyrs, shows that human motives cannot be all resolved into the impulse of self-preservation. It is true that the martyr dies in order to preserve what is more valuable than life, but it is playing on words to say that this is reducible to the merely vital impulse to self-preservation. If it is said that martyrdom in the Christian Church was endured in the hope of a heavenly reward considered merely as payment, I reply that this altogether mistakes the ethical character of Christianity. If argument is needed, we have only to point to those instances of martyrdom to duty which abounded in classical history, among men who had no definite hope of an eternal reward.

Darwin's theory of Conscience. Its inconsistency with facts.—For our present purpose, Conscience may be defined as that power which controls the lower motives. Darwin, in his *Descent of Man,* recognises the existence of such a power, and suggests that it consists in the stream of hereditary social instinct, asserting itself against momentary deviations into selfishness;—so that, when a man is condemned by his conscience for murder, or theft, or falsehood, this is nothing more than the voice of the habitual and hereditary instinct which impels him to regard the interests of society by respecting life, property, and truth, against the momentary deviation from this instinct into which he has been led by momentary temptation. I cannot imagine any theory which is more completely contradicted by facts than this. If it were true, the most imperative dicta of Conscience would coincide with the most universal organic instincts. But the fact is the direct contrary. The most universal of all organic instincts is self-preservation;—the chief command of Conscience is self-renunciation and self-sacrifice. Were this theory true, the tendencies of Conscience would be strong in proportion to the length of the ancestry from which they have been inherited, and its clearest commands and its greatest strength would be an inheritance from the ape and the newt. But so far is this from being true, that Conscience has never been stronger than in those Christian martyrs who faced death in the amphitheatre

rather than deny a Lord whose name was unknown to their fathers.

There is no doubt of the fact on which Darwin bases his theory of Conscience; namely that, as we have seen in a previous chapter, the oldest habits and instinctive tendencies are the most tenacious.[1] But though this is true, it is not the explanation of Conscience;—it is the explanation of a fact of an opposite kind, namely that culture, civilization, and religion, have constantly to struggle against the tendency of the characters of the savage and the beast to return.

Automatism is materialistic Necessarianism.—Automatism is much more than a mere reproduction of the older Necessarianism. The older Necessarianism maintained that mental action was as rigidly subject as physical action to the law of causation; but it was, or might be, a spiritual theory, inasmuch as it recognized the action of Mind as an agent. Automatism denies this, and is, in fact, Necessarianism on a basis of pure materialism.

Summary.—The error of Automatism appears to have arisen from the habit of regarding facts of observation and physical methods of research to the exclusion of all others. But facts of consciousness are equally real with facts of observation, and physical methods are not the only methods of research. In the science of Mind, consciousness is self-evidently the only possible source of the most important part of our knowledge. There might be, and there was, a science of Mind from data of consciousness only, before its study was affiliated to physiology, connected with facts of observation, and pursued by methods learned from physical experimentalists; but a science of Mind without data furnished by consciousness, and relying altogether on observation and experiment, would be as impossible a science as acoustics in a world of deaf men. If —to suppose an absurdity—such a science of Mind had been

[1] See p. 93.

worked out, Automatism could not be refuted, and would appear plausible. But Consciousness tells us that thought, feeling, and will, may each be the cause or the effect of the other; and, further, it reveals the Will as a reality by showing that self-control is possible;—truths which the automatic theory denies, or at least ignores.

Huxley on the Freedom of the Will.—In the present chapter I have maintained the distinctness of the Will. This is equivalent to maintaining its existence. Respecting the further question of what is technically called the Freedom of the Will, I have not now anything to add to what is contained in the chapter on that subject in my *Scientific Bases of Faith.* I conclude by quoting, from memory, a saying by Prof. Huxley, who, though a necessarian and an automatist, has here shown himself able to do justice to the opposite view. "In my opinion," he says, "the controversy about free-will and necessity will ever be a drawn battle; and for all practical purposes this is equivalent to the partizans of freedom gaining the victory." I can adopt this summary of the position, though I am myself a believer in freedom.

NOTE.

THE FREEDOM OF THE WILL.

THE following extracts are from an able article on Atomic Theories in the *North British Review* for March, 1868:—

Quotation from the "North British Review."—"A force acting at right angles to the direction in which a body is moving, does no work, although it may continually and continuously alter the direction in which the body moves. No power, or energy, is required to deflect a bullet from its path, providing the deflecting force acts always at right angles to that path." P. 223.

"The atoms may, as Democritus believed, build up a huge mechanical structure, each wheel of which drives its neighbour in one long inevitable sequence of causation; but you may assume that beyond that ever-grinding

wheel-work there exists a power, not subject to but partly master of the machine; you may believe that man possesses such a power, and if so, no better conception of its manner of action could be devised than the idea of its deflecting the atoms in their onward path to the right or left of that line in which they would naturally move. The will, if it so acted, would add nothing sensible to, nor take anything sensible from, the energy of the universe. The modern believer in Free Will will probably adopt this view, which is certainly consistent with observation, though not proved by it." P. 224.

Compare the following, from my *Scientific Bases of Faith*, p. 81.

Quotation from the "Scientific Bases of Faith."—"No one supposes the will of man to be, like that of God, an absolute Cause, or origin of a chain of causation. The most which is claimed for it is that it is capable of altering the direction of the chain of cause and effect, by acting not *in* the line of causation but *upon* it."

The words "not *in* the line of causation but *upon* it" are a quotation; I do not remember from whence.

Boussinesq on the mathematical expression of Freedom.—The foregoing was written before I had read a remarkable article in the *Contemporary Review* of June, 1878, by Paul Janet, giving an account, in unmathematical language, of M. Boussinesq's attempt at mathematical proof, not indeed of the reality, but of the possibility, of self-determination and moral freedom. I quote the following:—

"M. Boussinesq's idea consists in utilising in favour of the possibility of moral freedom, a theory familiar to geometers under the name of singular solutions, and also sometimes spoken of as Poisson's paradox. Agreeably to this theory, there may be, M. Boussinesq holds, cases of complete mechanical indeterminism;—that is to say, cases where a motor, having reached certain points called by the author points of bifurcation, may indifferently take one or two different directions, while in either case equally satisfying the mathematical equation.

* * * * *

"Under such a supposition we see that an extra-physical, extra-mechanical action might be the effect of a directing power. The author ingeniously compares the will to an engineer who, having to construct a canal along the summit [or rather the ridge] of a hill, may at all points of that 'singular' course distribute at pleasure the water of the canal into the one or the other of the two adjacent valleys, without having to make it deviate from its natural tendencies. There would thus, according to M. Boussinesq, be cases occurring only under very special conditions no doubt, and as difficult, even the simplest of them, to produce artificially as to make a cone stand on its apex, but still cases theoretically possible,—cases, I say, in which the initial state of a system would not involve completely determined tracks for phenomena;

—those tracks would admit of numerous 'bifurcations,' which, once given, would reproduce themselves indefinitely, and would thus permit the continual existence of a directing power, charged at every moment with the determination of directions.

* * * * *

"Thus the flexibility of life would be compatible with the rigour of mechanical law.

* * * * *

"I know no one except Poisson, continues M. Boussinesq, who has endeavoured to make use of singular solutions in mechanics. He does this in his important paper on Integrals published in vol. vi. of the *Journal de l'École Polytechnique.* He has not omitted to point out the difficulty they raise from the point of view of an absolute determinism. But, taking no heed of vital phenomena, he regards them as affording a paradox well worthy to exercise the sagacity of mathematicians, which he for his own part has no hope of throwing light on, though no doubt he has worked at it.

* * * * *

"Here is the passage from Poisson, a remarkably significant one :—'The movement in space of a body subject to the action of a given force, and starting from a given position and with the velocity equally given, ought to be absolutely determined. It is therefore a sort of paradox that the differential equations on which movement depends should be satisfied by several equations [? solutions], which fulfil moreover the initial conditions of movement. This difficulty, which does not appear to have been remarked, well deserves the attention of geometricians.'

* * * * *

"The presence or absence of singular solutions, and of the flexibility that they admit in the chain of facts, M. Boussinesq goes on, seems to furnish a geometrical character adapted to distinguish essentially vital movements—above all such of them as are voluntary—from the movements accomplished under the exclusive empire of physical laws. An animated being would consequently be one whose conditions of movement would admit at very close intervals, or even continuously, by means of the indeterminism to which they gave rise, the intervention of a special directing principle."

The foregoing very remarkable observations appear to show that absolute determinism is not a doctrine of abstract mathematics, and therefore need not be true in dynamics. Oersted, if I remember right, said that organization is nature's higher mathematics ; and these considerations show that it is conceivably possible for this higher mathematics to allow of a place where indeterminism and freedom may come in.

CHAPTER XXXIII.

HABIT AND VARIATION IN HISTORY.

The Science of Life and Mind has been fully systematized.—We have in the foregoing Chapters traced the outline of the sciences, or rather the single science, of life and mind, regarded as consisting of manifold applications of the two principles of Habit and Intelligence. That science, though at present in a state of very rapid advance, is fully systematized; a vast number of its problems remain to be solved, but a fundamental revolution in the mode of conceiving of the problems appears as impossible in the science of life and mind as in dynamics or in astronomy. The same is true of all the mathematical and physical sciences;—the outline has been drawn, and what remains to be done consists exclusively in filling it up.

The Sciences of the Results of Man's Mental Activity have not yet been systematized, including those of Language, Art, and Society.—But there is another group of sciences which have not yet been thus systematized. No doubt they admit of systematization, but the time for doing this work is perhaps not yet come. The sciences I speak of are those whereof the subject-matter consists of the results of the activity of the human mind, and the laws by which the mind acts under particular conditions. I cannot attempt even a complete enumeration of this group of sciences: but the most important, or at least those which have been most nearly reduced to systematic form,

are the science of Language; the science of the fine arts, or Æsthetics; and the science of society, or Politics.

The Laws of these subjects depend on the Laws of Mind, but the converse is not true.—The subjects of these three sciences—that is to say, language, art, and human society—are all products of the mind of Man; and, consequently, their elementary laws must depend on the laws of mind, while the laws of mind do not in any degree depend on them; so that these sciences depend on psychology, in somewhat the same way that biology depends on chemistry, or dynamics on mathematics.

The Intelligent and the Habitual elements in Language.—First, as to Language. In all mental action whatever, as we have endeavoured to show, there is an habitual element and an intelligent element, which, though they may be separated in thought, are always combined in fact. Language, being a product of mental activity, may be expected to indicate the action of these two factors; and such is the case. It would be superfluous to argue for the obvious truth that all language involves a habitual principle: we learn to use language by habit. But it is also obvious that language, at least when it is used as the means of the most elementary reasoning, involves a logical principle: and if the conclusions of the present work are true, the logical principles involved in all thought belong to Intelligence, and not to Habit. But without going back on that question, it is obvious that the power of learning words by memory, and the power of combining them into sentences that have a meaning, are distinct powers; and even those who do not agree with me as to the absolute and fundamental difference between Habit and Intelligence, will agree that the distinction between the two in the use of language is real, and of great importance. Memory supplies the words, and Intelligence combines them. A person without intelligence might know the names of things, but he could not combine the words into sentences having a meaning; and this is the case with some

idiots. A person without memory, on the contrary, might conceivably think, but for want of knowing the necessary words he could not express his thoughts in words. Memory and Intelligence are thus both necessary to the use of language; and as memory is a case of Habit, it follows that Habit and Intelligence co-operate in the use and in the formation of language, just as they do in organization and in mind. In the present state of the science of Language, this is not so evident as it will be at some future time. The science of comparative grammar has not as yet got beyond comparative etymology; the students of the science are at present concentrating their attention on the habitual element in Language, namely the words; this is needful at present, and may probably continue to be so for a long time. But it will not always be so; a science of comparative syntax will be possible, so soon as materials enough have been accumulated. By the formation of such a science, the logical element in Language will be brought into the same prominence, and may perhaps come to be as well understood, as the habitual, or verbal, element is now. It is not too much to hope that some fellow-countryman of Bopp and Grimm, or perhaps of Sir William Hamilton or of Professor Boole, may yet so trace the connexion between the laws of language and the laws of logic as to throw light on both. I am not able to make a beginning at that subject. I go on to show how close is the resemblance between the action of the habitual principle in organization and in language.

Language is an Organism.—Language is an organism. This is no mere metaphor. The definition of an organism is, that it consists of parts which are all in functional relation to each other; and the words of a sentence are thus functionally related.

As Life constructs the Organism, so Thought constructs Language.—Organization is not the cause of life, but life is the cause of organization. High organization is, however, necessary to any

high development of life: life constructs the organism to be at once its dwelling and the means of its action. Just so, language is the result of thought, but a highly developed language is necessary to any high development of thought: thought has constructed the organism of language in order to use it as an instrument. Considering the unlikeness between the subjects of the analogy, the analogy itself is wonderfully close between the action of life in building up the organism, and the action of thought in constructing language: each forms an organism to be its instrument.

Variability of Language, both in the forms of Words and in their Meanings, compared to Variation in the forms and the functions of Organs.—All habits are gradually variable; and habits of using particular words are peculiarly so: that is to say, the words themselves are variable. Words vary both in their forms and in their meanings. We have argued in the earlier part of this work, that the characters of organic species are variable, with little or no limit as to the amount of change, if only time enough is allowed; and that all organisms which are morphologically similar, are so by reason of being descended from the same ancestors. If this is true, any difference between parts which are morphologically the same—as, for instance, between the leg of the dog and that of the horse—are due to variation in the course of their descent from their common ancestor; and such variation is a parallel fact to the variation that takes place in the form of words when a word which is fundamentally the same is found in different languages. No one doubts, for instance, that the German word *heide* and the English *heath* are forms of the same word, and that the similarity of the two is due to a common original. We usually speak of the *descent* of living races, and of the *derivation* of words; but it is not a violent metaphor to speak of the *derivation* of the former, and of the *descent* of the latter; and both are cases of the variation of habit.

Words also change their meanings, even within the limits of

the same language, while their forms remain;[1] and this has its parallel in the fact that organs frequently assume new functions, as in the case of those fishes whereof the swim-bladder assumes the function of lungs.[2]

Rudimentary Organs comparable to Silent Letters. — We know moreover that some animals have rudimentary and useless organs, such as the leg-bones of some serpents and the wing-bones of the wingless birds, the only intelligible explanation of which consists in the supposition that they are inherited from ancestors which had the corresponding organs in a developed and working state. These rudimentary organs have been compared to the silent letters used in spelling many words, especially in French and in English. This analogy is not merely fanciful, but real. The silent letters were once sounded; —the rudimentary organs were once developed and at work. The silent letters mark the origin of the word; the rudimentary organs mark the descent of the species; and, as all naturalists admit, they mark its true affinities.

Morphological Correlations independent of Function, comparable to Inflections without Meaning.—There is another very curious parallel between the laws of organic morphology, and the laws of what may, by a very slight metaphor, be called the morphology of language. We have seen that there are some morphological characters in organisms which are due to laws of

[1] As the strangest instance of this that I can think of, I will mention the word *implicit*. *Implicit* is properly opposed to *explicit*, and means *implied* as opposed to *expressed*: but implicit faith and obedience have come to mean blind faith and obedience. The history of the change in the meaning of the word is, that implicit faith became a theological expression, signifying the faith which a man was credited with having in a doctrine to which he was too ignorant to attach any meaning, provided he believed in the authority of the Church, on the authority of which the doctrine was to be believed. Thus, a man who was too ignorant or too stupid to know what the Church taught on the subject of transubstantiation, would nevertheless be credited with implicit, or implied, faith in that doctrine, provided he only believed that the Church which taught it could not err.

[2] See p. 197.

correlation merely, and appear to have nothing to do with the adaptation of structure to function. Such is the fact that in man there are five toes on each foot as well as five fingers on each hand. It is as impossible to assign any purpose for such a correlation as it would be to assign a purpose for the laws of crystalline formation; they are not adaptations, they are nothing but correlations. There are in some languages correlations which may be compared to these: the best instance is that of the inflections of Greek and Latin adjectives, which contribute nothing to the meaning, and are only added from a principle of correlation with their substantives. The analogy is perfect. The logical principle in language corresponds to the adaptive principle in organization; and we find that there are correlations in organization which are not adaptations, and correlations in language which have nothing to do with meaning, and consequently nothing to do with the logical principle; they both consist in a kind of symmetry, which appears to be sought for not as a means but as an end.

Dr. Farrar on Language as an Organism.—"Philology has its various branches no less than botany (and zoology). Its analysis of words corresponds to the study of structure; its arrangement of linguistic families to classification; its examination of the functions of formative syllables to organography; even its *Lautlehre*, or study of sounds, to histology."[1]

Morphology and the Science of Language are Comparative Sciences, and also Sciences of Development.—Organic morphology and the study of language have both become comparative studies: the decisive step which first made the study of language really a science was taken when the study of comparative grammar, or comparative philology, was commenced: a science of language was impossible so long as its data were sought in only one or two languages. In the same way, the only

[1] From "Philology as one of the Sciences," by F. W. Farrar, M.A., *Macmillan's Magazine*, January, 1869.

scientific morphology is that which is based on the comparison of forms which are widely different, but not so different as to exclude a fundamental resemblance. And the more profoundly both comparative morphology and comparative grammar are understood, the more do their students succeed in discovering fundamental resemblances under the external appearance of total unlikeness. The science of language also resembles morphology in being a science of progressive change. I do not speak of embryology, because nothing is yet known, as far as I am aware, about language in its embryonic state; though the embryology of language, that is to say the history of its origin and earliest development, would be a subject of science, and a most interesting one, if the facts could be ascertained. But as morphology traces not only the graduated resemblances and differences between different species and different classes, but also the progressive changes during the life of the individual; so the science of language traces not only the graduated resemblances and differences between allied words in different languages, but also the progressive changes in the same language from century to century, amounting sometimes to total apparent transformation; such as, to mention one of the most remarkable of all perfectly known cases, the transformation of Latin into French.

Historical Science of the Fine Arts, involving the same principles as Organic Morphology and the Science of Language.—The same remarks apply, without more modification than the difference of the subjects renders necessary, to the Fine Arts. I speak of the scientific study of their history: their theory is a different subject. Concerning the theory of the Fine Arts not much is yet established, except that of music, which is well understood, at least in a technical sense. But a scientific treatment of the history of art is possible; and it is found to involve the same principles which are true alike of organic morphology and of the science of language. In art, we have to do with comparative morphology, and with

development and progressive gradual change. It is no metaphor to speak of morphology in art; the word is applicable with the most perfect literalness to those arts of which the object is form: architecture is perhaps the best instance. In any historical account of a style of architecture, or in any comparative account of styles which have a common origin, it would be almost impossible to avoid the use of language which sounds as if it were borrowed from organic morphology. Thus, in describing the progressive changes of English architecture, we say that from the time of the introduction of the pointed arch, by which Gothic was constituted as a distinct style, arches gradually became flatter, mouldings less bold, and ornaments more elaborate. Or in tracing the descent with modification (and in the word descent is implied an analogy with living beings),—in tracing the process of descent, I say, by which Roman architecture was modified into Gothic on the one side, and into Oriental or Saracenic on the other, we find that the arch, which was semicircular in the Roman style, became pointed in the Gothic, and in the Oriental acquired the "horse-shoe" form by becoming a somewhat greater arc than a semicircle. We use similar language when we describe how the leg of the quadruped is so modified as to be changed into the wing of the bat or into the paddle of a whale; and all these changes, those of organic morphology and the morphology of art alike, as well as the changes of language, come under the one law of the gradual variability of Habit.

Love of Slight Novelty is the Moving Power in the Progress of Art.—There is no doubt this difference, that changes in organic morphology are due to the action of totally unconscious forces, and changes in language are due to mental forces acting with very little consciousness; but changes in styles of art are made with full consciousness on the part of the artist. This difference, however, is not fundamental, if it is true, as we have argued throughout the present work, that organizing intelligence and mental intelligence are essentially the same. The love of slight

novelty for its own sake, though an unintelligent principle, is the moving or impelling, though not the controlling power, in the progress of art, in the direction both of improvement and of deterioration; without this, art would be either stationary or subject at most to few and slight changes; and this love of slight novelty, as we have already remarked, is closely connected with the law of the gradual variability of Habit.[1] On the other hand, the continuity which is so remarkable in the history of art, without which, indeed, art could not be said to have a history at all, is due to the constancy of Habit, and to the mental law that great or sudden changes are disagreeable.

Rapid Changes in Art. Substitution in England of Early Pointed for Norman.—It may be said that in point of fact the history of art is less continuous than we have stated it to be. I do not deny that it presents some very remarkable instances of rapid, if not quite abrupt change. Some of these, however, are cases merely of the introduction of a foreign style which has superseded the native one, as when the pointed Gothic architecture was introduced from France into Western Germany, and rapidly and completely superseded the old round-arched style. But the total change in English architecture from the round-arched Norman of Glastonbury to the Early Pointed of Salisbury is not to be thus accounted for. It appears to be a case of almost total transformation, effected without any extraneous cause, and in a very short time; and I believe this change nearly coincides in date with the transformation of the Norman kingdom of England into an English one. But this does not violate—on the contrary, it completes—the parallel between the history of the morphology of art and that of the morphological changes in the development of species, if it is true, as we have maintained in a previous chapter, that organic changes must have taken place at particular periods with exceptional rapidity.[2] A much more remarkable instance of sudden development in the history of art is that of the Great Pyramid, which is at once the oldest

[1] See p. 106. [2] See p. 394.

and the largest of all historical buildings, and shows a remarkable degree of geometrical science in its plan; and yet, as Piazzi Smith has remarked, we find no traces of any historical process whereby the art of such constructions attained to maturity, though it appears scarcely possible that pyramids should be destroyed, and not likely that they should remain undiscovered.

Intelligence in Art modifying the Materials given by Habit. Instance; Stained Glass in Gothic Architecture.—Although there is beyond doubt an intelligent, or logical, principle in Language, yet in the present state of the science of language we know very little of the mode of its action. It is otherwise in the history of Art: in the morphology of Art, as well as in organic morphology, the action of Intelligence is clearly traceable in modifying the results of unintelligent Habit. We have shown in a previous chapter how the organizing Intelligence works with the materials given to it by hereditary Habit, so as to modify for new purposes what is homologically the same organ, and yet so as to retain a much closer resemblance to the original model than is needed for the new purposes; as is seen, for instance, in comparing the wing of the bat with the leg of the quadruped. This action has its parallel in the history of Art, where the artist's purpose, which is the intelligent principle, modifies the action of the habitual principle of traditional style. The best, or at least the most curious instance of this that I know of, is the way in which the Gothic style of architecture was modified, without losing its distinctive characters, in consequence of the introduction of stained glass, the display of which became the chief aim of the architect.[1]

The same principles in Political Science. Continuity of History.—We have now to consider the application of the same principles to political science.

It has become a commonplace, that "constitutions are not made, but grow"; the same is true of language, of art, of society,

[1] See Fergusson's *Illustrated Handbook of Architecture*, vol. ii.

and of every product of human activity continued through successive generations; though it is not necessarily true of the product of the activity of a solitary worker or thinker. This is a result of the fundamental truth, that Habit is variable, but only gradually so. All historical research tends to show, more and more clearly, the continuity of history, and the impossibility of any progress which is not gradual. Destructive changes, no doubt, may be sudden, and so may death; but constructive changes must take place under the laws of life, and must be gradual, because they consist in, or involve, changes of Habit. It has been said, with a basis of truth though with much exaggeration, that

> "A thousand years scarce serve to form a state,
> A day may lay it in the dust."[1]

Constructive changes cannot be really at once profound and sudden; when they appear to be so, as in many of the revolutions of our own time, their profundity can only be tested by the durability of the result; and if it endures this test, we may be sure that such a revolution, however sudden it may seem, has been prepared by a gradual change in the minds of men. It is indeed a commonplace that all political change, if it is to be durable and safe, must be gradual; that constitutions must develop themselves, and must take time to do so. This is a consequence of the gradual variability of Habit.

We thus see that the law of the gradual variability of Habit underlies the analogous facts of organic morphology, of language, of the history of art, and of political history.

These analogies are general. We now go on to the subject of a remarkable special analogy, also based on the law of Habit, between the process of mental education and that of social and political progress.

Analogy of Political Progress to Mental Education.—All education consists in the formation of habits; and the acquisition of any new power as the result of education consists in the

[1] Byron.

exercise of that power becoming habitual, and in a great degree independent of consciousness and will. Thus, the process of learning one's own or any other language consists in the words and their meanings coming to suggest each other without effort, so that the reasoning process which is needed in order to understand or to form a sentence is in a great degree, if not altogether, performed in unconsciousness. By thus learning to perform as a result of unconscious habit what at first needed a conscious effort of will and thought, the immediate work to be done—whether forming a sentence, or practising an art, or whatever it may be—is done much more rapidly, while the attention is set free for other purposes. Learning an art, or a language, occupies the whole attention; that is to say, it absorbs the whole consciousness in so far as the consciousness is under the control of the will; but when the art has been thoroughly learned, it may be practised while a large share, if not the whole, of the attention is left at liberty to direct itself to other objects. Thus, a competent artisan is able to converse while at his work, unless it is exceptionally difficult.

Necessity of Permanence in Habits.—It is a parallel truth to this, that social and political progress mainly consists in the formation of social and political habits, of which laws are in a great degree the expression; and this progress is possible only on condition of actions becoming habitual after they are once decided on. It is, for instance, very important to have a good parliamentary constitution, but it is quite as important that its merits should not be constantly under discussion. Other legislation would be impossible if Parliament were always engaged in discussing projects for the reform of itself, just as the exchange of ideas would be scarcely possible if we had to be always thinking of the grammatical construction of our sentences. In a word, as education is possible only by actions becoming habitual, so political progress is possible only on condition of institutions becoming in some degree permanent. They are the greatest of political *bores* who think every opportunity a right one

for opening a discussion on the merits of any institution whatever, though the instinctive conservatism of mankind generally prevents them from being dangerous.

Conscious Functions are later developed than unconscious ones, both in the Individual and in Society.—Government.—Law.— All this is obvious enough. There is another parallelism between the mental development of the individual and the progress of society, which is equally real though not so obvious. The conscious functions are in all cases later developed than the unconscious ones, and are developed out of them; and it is scarcely a metaphor to say that this is true of political development also. Society acts unconsciously before it learns to act consciously. Government at first springs up spontaneously; nations at a later period learn to appoint their governments by a conscious and deliberate act; but the appointment of a government by a conscious national act would never have become possible, and could not have been thought of, if governments had not first grown into existence as a natural development of paternal authority.[1] The same is true of the origin of law. It is a truth which must be understood in order to make primitive history intelligible—and it is moreover a truth which legislators ought never to forget—that *custom is older than legislation* :—laws originate unconsciously in custom before they can be consciously modified by legislation; and legislation would be impossible if it had not a basis in customary law. This ought to be easily intelligible to those who live under the English system of law, in which common law has, or at least is supposed to have, its origin in immemorial custom, older than any statute.[2]

[1] See Sir Henry Maine's *Ancient Law*, Chapter V.

[2] The relation of written to unwritten law appears to have been somewhat different in the ancient republics from what it is in England. The twelve Tables of early Rome, and other ancient codes, according to Sir Henry Maine (*Ancient Law*, Chap. I.), were not additions to the customary laws already in force, but only written expositions of them. Their usefulness consisted in their publicity: for there is reason to believe that, previous to their publication, the ruling aristocracies were the exclusive guardians of the legal traditions, and abused the power due to that function.

Habit ought to be controlled by Intelligence. Conservatism and Liberalism.—Moralists constantly warn us against the dominance of habit, and politicians warn us against blind conservatism. They are right. Habit is an unintelligent force, and ought to be kept under the control of Intelligence and will; and mere blind conservatism is nothing else than the action of unintelligent Habit in politics. But it is only the law of Habit that makes the formation of character possible, whether in an individual or in a community; and therefore what we have to do with the habitual forces is not to destroy them (for this, were it possible, would be mental suicide), but to keep them under control, so as to be capable of modification at the command of Intelligence. This is true alike of the individual and of society. Politicians have been divided ever since political progress began, and will continue to be so until it has ceased, into two parties, or schools, which have borne various names at various times and places, but are known to us as those of Conservatism and Liberalism. It is felt by all that these names indicate a profound distinction, and it is felt by all who are anything more than mere partizans that this distinction does not coincide with the distinction of truth and falsehood, or with that of good and evil. The basis of Conservatism is in the permanence of Habit: the basis of Liberalism is in the possibility of Habit being controlled and modified by Intelligence.

The dominance of Intelligence over unintelligent Habit is imperfect in even the wisest individual men, and among nations it is well if it exists at all. Entire races, as for instance those of India, appear to regard the change of a custom or a law as impossible. To this blind conservatism is due the fact, which is illustrated in every page of history, that institutions have a tendency to outlive their usefulness. The best instance of this is probably the secular power of the Papacy, which in the early Middle Ages was no doubt a beneficial institution, but was a noxious one for many generations previous to its downfall.

CHAPTER XXXIV.

NATURAL SELECTION IN HISTORY.

In the preceding chapter we have spoken of the application of the laws of Habit and Variation to the facts of history. In this chapter we shall speak of the application of the law of Natural Selection to the same.

Production of new types of Character in Colonization.—We shall first speak of the physical action of natural selection, in producing new types of mankind by the process of colonizing new countries. I mean colonization as it is effected now, by the voluntary emigration of individuals and of families; not, as it took place in prehistoric and early historic times, by the migration of whole tribes together. In the first place, it is the most restless, ambitious, and energetic that emigrate; this characteristic, like all others, tends to become hereditary; and thus, from the very first, a difference of average character is established between the emigrant population and the parent stock. It seems certain that this cause has much to do with that peculiarity in the character of our North American kinsmen which is sometimes called energy and sometimes restlessness. In the second place, the different physical and social circumstances of the new country from those of the old will tend in various ways to modify character, and these modifications will also tend to be inherited. Lastly, there will be some individuals and families among the emigrating population to whom the climate of their new country is congenial, and others to whom it is comparatively unhealthy:

the former will have the best chance of surviving and of leaving descendants, while the latter die or abandon the country, in either case leaving few or no children; so that even without taking into account any direct action of the climate in adapting the people to itself, the action of natural selection in the course of generations will tend to make the colonial population consist exclusively of persons who are suited to the climate in virtue of their physical constitution. Now, it is scarcely possible to doubt that with any such peculiarity of physical constitution some peculiarity of mental constitution will be correlated, though we know nothing of the laws of such correlations. And thus will a new national character be formed ; just as, according to Darwin, acclimatization is effected partly by the self-adaptation of the race to the new climate, and partly by natural, or in the case of cultivated races by artificial, selection. It is true that in this process there is no moral element, and no certainty or preponderant probability of the new type of character being on the whole better than that of the parent race. But variety is ensured ; and variety for its own sake appears to be a part of the purpose of nature.

> "God fulfils Himself in many ways,
> Lest one good custom should corrupt the world." [1]

Natural Selection is true in the Moral World.—The process now described is a purely physical one, and in no way peculiar to human history ; indeed, there can be no doubt that new races of animals and of plants originate in this way, and have so originated in countless instances during the course of geological time. We now go on to speak of natural selection as a law of the moral world and a cause of historical progress.

History is determined by Man's Mental Nature.—The laws of Habit and Variation, as we have seen, are true of both the

[1] Tennyson's *Morte d'Arthur.* I have no doubt that Tennyson is perfectly aware of the thoroughly modern character of this sentiment, and the anachronism of placing it in the mouth of a king of the heroic age.

bodily and the mental functions; and, as we have endeavoured in the preceding chapter to show, those laws are applicable to the facts of human history. Now, human history is determined almost exclusively, not by the bodily, but by the mental nature of man;—not by that nature which he has in common with other animals, but by that which is peculiar to himself. The reason of this is, that the mental nature, which distinguishes man from the lower animals, is also that in which consists the superiority of one man, and of one race of men, to another. This is a case of the law that mental characters are more variable than bodily ones. But though it is a case of a biological law, it is none the less the ground of the truth that history is associated rather with the moral than the physical sciences. It is true that such physical causes as those which belong to geography and climate have had a most powerful influence on the course of history; but this does not make history a physical science: just as the facts of organic life cannot be understood without reference to the external conditions of life in the earth, the waters, and the air, and yet the laws of life are distinct from those of matter.

Victory in Human Conflicts depends on Moral Causes.—The law of natural selection implies that the life of every species is an incessant struggle for existence; and what causes advance in organization is, that victory in the struggle falls, on the whole, to the superior races. This is as true of man as of any other species; the whole history of man is a tale of struggle and conflict;[1] but what constitutes the peculiarity of human history is this, that among the lower races the conditions of success are almost exclusively physical, while with man they are almost exclusively moral. Among animals, victory, the preservation of life, and the chance of leaving offspring, depend on such qualities as fleetness, strength, keenness of sight or of scent, or, at the highest, on sagacity and cunning. The same may have been

[1] What follows has been in a great degree suggested by a most able article, entitled "The Natural History of Morals," in the *North British Review* of Dec. 1867.

true of man in his earliest prehistoric condition, when as yet he was but little removed above the higher animals. But in any state of man which history records, and doubtless for long ages before the dawn of history, victory has been determined, on the whole, not by physical but by moral superiority.

This will probably be assented to as self-evident; nevertheless I think the conditions on which depend the success and predominance of races and nations are generally misunderstood. It is the most obvious, and, I suppose, the commonest notion, that victory belongs as a matter of course to the most courageous. Other things being equal, this no doubt is true. But it is very seldom that other things are equal; and of all moral endowments, there is probably none in which men are more nearly equal than in what is significantly called "mere animal courage." The Duke of Wellington, a very competent judge, used to say that as a general rule all men are brave; and there is no doubt of the fierce valour of many Asiatic tribes; yet, with some partial exceptions in the history of the Mahomedan conquests, Asiatics, from the time of Miltiades till now, have always given way before Europeans. The causes of victory must reside, not in that lowest moral quality with respect to which men are comparatively on a level, but in those higher moral qualities with respect to which they differ indefinitely.

Superiority of Power in a primitive state is due to the Domestic Virtues.—The most commonplace of all the conditions on which victory depends is the relative number on each side. In our times, this in no way depends on any moral superiority of the more numerous army, or of the nation that sends it forth; but it was not so at the beginning of civil society. We know that primitive tribes tend to break up into fragments, as in the case of the separation of Abraham and Lot, and of Jacob and Esau.[1] We have not, so far as I am aware, any

[1] I believe the Book of Genesis, from Abraham forwards, to be mainly historical; but whether it is so or not, the incidents referred to in the text are not the less characteristic of the period.

direct evidence on the subject; but from what we know of human nature, we may safely infer that the tendency to separate will be greatest among a people of selfish and contentious temper; while those in whom the domestic virtues are more highly developed, and the civic virtues are coming into existence, will be more likely to stay together, to live under the same government, and consequently to form a united and powerful tribe, able to overcome and conquer those tribes which are kept in a divided state by their deficiency in the domestic and civic virtues.

The Political Virtues.—This cause of superiority can exist only so long as there is room for tribes to split up and separate. It will come to an end when the increase of population is sufficiently great to prevent them from spreading at will; when agriculture succeeds to a pastoral life, and tribes consolidate into nations. But when political communities are larger, and wars are waged on a larger scale, the conditions of success are even more distinctly moral. The first of these conditions are fidelity, and what is intimately connected with this, the capacity for obedience. This subject is systematically misunderstood by Western Europeans, who often appear to think that self-assertion and untameableness are the best basis for the political virtues. It may be true, though I much doubt it, that the greater is the difficulty of taming a race of men into civilization, the nobler is their character when they have been so tamed. But untameableness is simply the character of the savage, and freedom and the love of freedom are of no moral worth whatever unless they are based on loyalty and the capacity for obedience. Fidelity, loyalty, and the capacity for obedience are moral qualities of a very high order; and it is these which make political and military combinations possible, and give political and military power.

The Civic Virtues.—Thus the domestic virtues which keep a tribe together are those which conduce to power and to victory

at the first dawning of civil life in the nomadic and patriarchal state; and the political virtues are those which conduce to power and to victory in a more advanced state of society. We may perhaps say with some approximation to accuracy that the former are characteristic of pastoral life, and the latter of agricultural. But there is a third kind of virtues which are characteristic of civic life, and are called from them the civic virtues. It is not very easy to define in what civic virtue consists, but it is happily so well known among us that no definition is needed in order to make our meaning intelligible. It may perhaps be defined as the transference of loyalty from a superior to the community. It is shown in all history, from the Greek republics onwards, how the civic virtues form the best and surest bases of political and military power.

Thus in the strife of tribes, of races, and of nations—in the political as in the physical world—a process of natural selection goes on, of which the tendency is to give the victory to the best.[1]

At first Vanquished Races were destroyed: afterwards they were subjugated. Progress due to Conquest.—In the earliest periods it is probable that wars were always wars of extermination; and under those circumstances the effect of natural selection must have been simply that the inferior races perished and the superior ones survived. This process takes place even at the present day, where the inferior races are unable to adopt the ways of civilized life, though not now by massacre. It is going on before our eyes in Australia and New Zealand, and the comparatively benevolent disposition which civilized men have now acquired appears unable to arrest it. This is the way in which natural selection acts as between contending races of animals—namely, by the destruction of the weakest. But at a later

[1] On the subject of the tendency of virtue to confer political power, see a remarkable passage in Butler's *Analogy of Religion*, Part I. chapter iii. (pp. 71 and 72 in Bishop Fitzgerald's edition).

period, when men had become less brutal, wars ceased to be wars of extermination, and became wars of conquest. And when one race is thus subjugated by another without being destroyed, a new set of conditions arises, to which there is nothing similar in the animal world. This is not a subject of merely historic or prehistoric research, but is of the deepest political interest and importance. Races which become dominant, whether through innate force of character or through favouring circumstances promoting their advancement in civilization, appear to have a power of raising the conquered races to their own level. The best instance of this is probably to be found in the results of the Roman conquest of Western Europe.

The Same Principles in Peaceful Progress. Justification of Freedom.—But when nations, as distinguished from mere empires, are consolidated, conquest ceases to be an agency of improvement; and thenceforward historical progress must be chiefly due to the arts of peace, industrial as well as political. But progress is still due to a process of natural selection, though natural selection is now applied, not to races of men, but to institutions and to ideas. In the peaceful strife of our modern times, however, as in the warlike strife of the ancient, the principle to which progress is due is still the same—namely, free competition and the victory and preservation of the best. It is only on this principle that freedom can be justified. The ever-repeated argument against freedom is, that the mass of mankind, when they have attained it, do not know what to do with it. This may be true; but, if it is proved to be true, freedom is none the less a means of good. It is a law of the organic world that many more seeds must be produced than can possibly mature their products; and it is a law of the human world that an immensely large proportion of effort shall be wasted. But it is only by permitting freedom of effort in all directions, with its unavoidable concomitant of waste, that any valuable results can be achieved. Where careers are open, many men will struggle

into positions for which they are unfit. Where industry and commerce are uncontrolled, many disastrous blunders will be made in the exercise of this freedom. Where the expression of thought is free, much will be published that is foolish and mischievous. Hence it will always be possible to find arguments against freedom, which so far as they go are perfectly valid. The reason that modern political society is right in disregarding them is that they are outweighed by immeasurably stronger arguments on the other side. Open careers may tempt men to waste their lives, but careers must nevertheless be open in order that the best men may be selected. Commercial freedom may tempt men into disastrous speculations, but commerce and industry must be free in order that it may be ascertained, by actual competition, in what way the industry of each district and each nation may be most profitably directed, and how commerce may be most successfully transacted. And freedom of thought—that is to say, freedom of discussion and publication—may lead to the dissemination of pernicious error, yet freedom of publication is necessary to the progress of knowledge, and free and fair discussion is the only means by which error can be killed. In a word, it is necessary that in the world of human society there should be full freedom (within the limits of morality and public safety) for the spontaneous variation of character, action, and thought, in order that competition may select and preserve the best results, while the worthless ones perish.

The foregoing part of the present chapter, as well as the whole of the preceding, have been reprinted with little change from the first edition of this work. What follows is an attempt to apply the principles of natural selection in history to a special case of great interest.

Remarks on Mr. M'Lennan's Theory of "Primitive Marriage."—It is proved by a great amount of evidence, that in the earliest human society, kindred was reckoned through the

mother alone; so that family names, tribal rights, and property, so far as these existed, were inherited in the female line. Marriage was communal, which is nearly the same thing as saying that it did not exist at all, and the authority of the father was unrecognised.

The transition from this society to the patriarchal, with marriage in the modern sense and full paternal authority, was probably the greatest step ever made in human progress.

The investigations published in Mr. M'Lennan's *Primitive Marriage*, make it probable that the original impulse to this transition came from the custom of bride-stealing. While the earliest organisation lasted, under which the tribe had all their property, including their wives, in common, the formation of a family, based on marriage, would be possible only by the separation from the tribe of a man with his wife or wives, going away to lead a solitary life; and though this may have often taken place, yet the moral gain would be lost in consequence of the intellectual degeneracy caused by solitude, and no progress would result. The introduction of marriage, and with it of paternal authority, without breaking up the tribe, was due to bride-stealing. Primitive tribes being constantly at war, wives from other tribes could be obtained only by capture. Women were stolen like other property; and wives, like other property taken in war, were not communal but private. (Maine, in his *Ancient Law*, mentions a somewhat similar privilege granted by the Romans to property acquired by war.) From this root have sprung the customs as to marriage, paternal authority, kindred, and succession, which are now universal, among at least the higher races of mankind.

So far I think Mr. M'Lennan has almost proved his case; but I cannot agree with him in the theory whereby he endeavours to account for the wide prevalence of bride-stealing in early times. He thinks the impulse to it came from the prevalence of female infanticide: in other words, that primitive men preferred to steal their women instead of rearing them. This seems to be an impossible explanation. The practice of female in-

fanticide would tend to destroy the race, and thus would leave no permanent result. Any race killing all the female infants would perish in one generation; any race killing a large proportion of them would gradually die out; so that a process of natural selection would destroy the races practising infanticide, and preserve the rest. Moreover, the evidence of the prevalence of female infanticide among primitive races seems very weak.[1] Mr. M'Lennan reasons as if every tribe could supply itself with wives by stealing them; but this is impossible, for the same reason that the last beefsteak would soon be eaten if all were cattle-stealers, and none cattle-breeders.

Mr. M'Lennan's hypothesis, to account for the cessation of infanticide, is equally unsatisfactory. He thinks it was abandoned after bride-stealing became general, for fear of incurring the vengeance of the kindred of the mothers of the infants. It appears improbable that the kindred would either know or care what was done with the children of a woman who had ceased to belong to them.

The reasons for the prevalence of the custom of bride-stealing, over and above the predatory habits of barbarians, are in my opinion the following:—

1. The desire of every man to have a wife of his own. Perhaps we ought to add the desire of every woman to have a husband of her own; but I do not know that we have evidence as to whether this has any effect.

2. The instinctive desire to mix the race. It would be difficult to find proof of this, but the benefit of slight mixtures of race is certain, and it is probable that an almost unconscious instinct would prompt primitive men to seek this benefit.

The custom, being thus originated, would be encouraged from the following reasons:

3. The children of such unions, having fathers to care for them, would be better cared for than others, and would be more likely to live and be strong.

[1] See Sir John Lubbock's *Origin of Civilization*, p. 95 (3rd edition).

4. The children of such unions, being of mixed race, would be physically superior to others.

But more importance is probably to be assigned to a different reason.

5. Paternal or patriarchal authority having thus come into existence, gave such political coherency to the tribe, that a tribe possessing it would be superior in war to any tribe living under the old anarchical organization.

Thus, by a process of natural selection, bride-stealing became general; and, though it has died out, the institution of marriage, and the patriarchal organization of society, to which it led, have been perpetuated in a modified form.[1]

[1] The foregoing criticism on Mr. M'Lennan's theory was read to the Anthropological Section of the British Association in 1874, when Sir John Lubbock expressed his general agreement with it. On the entire subject, see the chapter on Marriage and Relationship in his *Origin of Civilization*.

CHAPTER XXXV.

INDIVIDUAL AND SOCIAL ORGANIZATION.

Division of Labour in the Organism and in Society. Society is an Organism.—In the preceding chapters, we have seen how the principles of Habit, Variation, and Natural Selection apply to the historical sciences, as well as to the sciences of life and mind. In addition to these, we purpose in the present chapter to speak of a special set of resemblances between the bodily life of an organism and the life of a society. The fundamental law of vital and of social organization is the same; namely division of labour. The definition of organization is functional relation between parts; and, under this definition, a society where labour is divided—or, to speak more accurately, a society where employments are distributed—is not metaphorically but literally an organism. The expression "physiological division of labour," has been borrowed by biology from political science, to signify what is called in less suggestive language the "specialization of functions." But to speak of the division of labour, whether in the individual or in the social organism, expresses only half the truth. The more unlike are the members one to another, and the completer is the division of labour between them, the more decided also is their mutual dependence, and the greater is the power of the entire organism, by means of the combined action of its various unlike members, to achieve results which could not be achieved by any union of like parts. To use technical language, the greater is the differentiation, the completer is also the integration. This, which is

true of organic life, is equally true of social life. It is too familiar a truth to need insisting on, that the efficiency of a society depends on division of labour, and on ability to combine the several actions of the various members among which the labour is divided; and it is equally obvious to any one who has the slightest knowledge of comparative biology, that the efficiency of the organic apparatus depends on the same conditions; namely on the distribution of functions between the several parts, and the consequent ability to combine the different actions of those parts.

Social, like Organic Development, is from the Simple to the Complex.—There is also this resemblance, that the development of the community, like that of the individual organism, is from the simple to the complex.[1] In the simplest forms of human society there is no division of labour, except what is determined by the differences of age and sex. With social and political advance, the division of labour goes on constantly increasing.

The most highly organized are the largest and the longest lived.—Further, the more highly organized among organisms grow to the largest size, and live the longest; those of the lowest organization are mostly microscopic, and live for only a few days, in remarkable contrast with the Whale, the Elephant, and Man. It is the same in societies; the communities of savages are very small, and last for but a few generations, unlike the kingdoms and republics of civilized men. Further, the highest organisms have been derived by descent, with modification, from the lowest; and the most highly civilized societies have been developed out of savage ones by gradual advance.

Constant change of Material.—Moreover, the material of the organism is constantly ceasing to live, and is cast off by excretion, while new matter is brought in and vitalized; so that the same organism, at successive periods, does not consist of the

[1] See chapters v. and vi.

same matter. Just so, members of the community are constantly dying, while others are born; so that the same community, at successive periods, consists of different individuals.

Nutritive and Nervo-muscular Organs. Industrial and Political Organization.—It is a remarkable point of special resemblance, that in all animals except the lowest, there are two distinct sets of organs, namely the nutritive and the nervo-muscular. Similarly, the organization of society is twofold, industrial and political: the industrial organization of society is comparable to the nutritive organization of the animal, and the political organization of society to the nervo-muscular organization of the animal.

Ground of the resemblance. Life is in both a mode of Activity. Habit. Intelligence.—The parallel here drawn between the organic life of the individual and that of society is much too close to be accidental; it must be due to some common ground in the nature of both. This common ground consists in these three truths:—

1. Life, in both the individual organism and in society, is a mode of activity. Perfectly stagnant life would be a contradiction.

2. The laws of Habit are operative in both; and

3. Habit and the other unintelligent forces are in both controlled by Intelligence; to the action of which all advance in organization, whether individual or social, is due;—organizing Intelligence in the individual organism, mental Intelligence in society.

We have in conclusion to note two important differences between individual and social organization.

Social Organization does not depend on Structure.—In the individual organism, organization depends on structure; in other words, the relation of parts with respect to function

depends on their relations of position and form. In societies this is not the case.

In Society the whole exists for the parts.—In the higher animals, the sentient life is concentrated in the brain; and from this concentration or centralization of life, it follows that the parts exist for the whole. In societies, on the contrary, the whole exists for the parts.

NOTE.

HERBERT SPENCER ON THE SOCIAL ORGANISM.

It will be perceived that the ideas of the foregoing chapter are borrowed from Herbert Spencer's very ingenious and able essay on the same subject.[1] I think his leading idea is true and most valuable; but, not satisfied with pointing out the general resemblance between the principles of organization in the individual and the social organisms, he has attempted to draw a detailed parallel between particular organs and functions in the two, in a way which appears untenable. This will be shown by stating the various parallelisms which he discovers, in a double tabular form.

The working class.	The nutritive system.
The trading class.	The circulating system.
Commodities.	Blood.
Money.	Red blood-corpuscles.[2]
Roads, canals, and railways.	Blood-vessels.
Double lines of rail.	Double set of vessels (arteries and veins).
The governing class.	The nervo-muscular system.
Local and executive governments.	Ganglia, including the spinal cord.
Parliament.	The cerebral ganglia.
Telegraph wires.	Nerve fibres.
Telegraph wires used in working railway traffic.	Nerve fibres controlling the arteries.

[1] Republished in the second volume of his collected Essays.

[2] "Silver and gold have to perform, in the organization of the state, the same function as the blood-corpuscles in the human organization. As these round discs, without themselves taking an immediate share in the nutritive process, are the medium, the essential condition of the change of matter, of the production

I cannot see that any injustice has been done to Mr. Spencer in the foregoing summary of some of his special conclusions. I do not, however, mean to imply that they are nothing more than a mass of incongruities. His general parallel between the processes of development in the individual and in the social organism is most valuable. He has laid himself the more open to such a criticism as mine by quoting a passage from Hobbes, in order to show its incongruities, which appear to be no greater than his own. I subjoin part of it, quoting the words exactly, but putting it into tabular form. We must mention that Hobbes regards the "great leviathan called a commonwealth" not as a natural growth but as an artificial production.

The *sovereignty* is	An artificial *soul*, as giving life and motion to the whole body.
The *magistrates* and other *officers* of judicature and execution . .	Artificial *joints*.
Reward and *punishment*, by which, fastened to the seat of the sovereignty, every joint aud member is moved to perform his duty, are	The *nerves*, that do the same in the body natural.
The *wealth* and *riches* of all the particular members are . . .	The *strength*.
Salus populi, the *people's safety*	Its *business*.
Counsellors, by whom all things needful for it to know are suggested unto it, are	The *memory*.
Equity and *laws*	An artificial *reason* and *will*.
Concord	*Health*.
Sedition	*Sickness*.
Civil War	*Death*.

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of the heat and of the force by which the temperature of the body is kept up and the motions of the blood and all the juices are determined, so has gold become the medium of all activity in the life of the state." (Liebig, quoted by Spencer.)

The theory referred to the above passage is, that the red blood-corpuscles are *carriers* of oxygen to the tissues, and of carbonic acid away from them; so that they are used in the process of nutrition without being consumed. It admits of no doubt, that we may look upon the red blood-corpuscles "as specially subservient to the vital activity of the nervo-muscular apparatus; since it is one of the most important conditions of that activity that these tissues shall be supplied with duly oxygenated blood, and that the carbonic acid which is one of the products of their decomposition shall be carried away. And this view is in complete harmony with the fact that the proportion of red blood-corpuscles in the blood bears a close relation to the amount of respiratory power in different classes of Vertebrata, as shown in the quantity of carbonic acid set free, and the amount of heat generated."—Carpenter's *Human Physiology*, p. 278.

CHAPTER XXXVI.

CONCLUSION.

Purpose of this Work.—In the present work we have endeavoured to show, in the first place, that Life, with the power of forming habits and perpetuating them by hereditary transmission, is distinct from all merely physical and chemical forces;—and in the second place, that Intelligence, though co-extensive with Life, is distinct from the merely habitual powers. In other words, Life transcends Matter; and, within the sphere of Life itself, Intelligence transcends Habit.

Contrast of Habit and Intelligence.—Habit and Intelligence are not only distinct but contrasted. Habit is conservative, and can work only on the lines of the past;—Intelligence is progressive, and works with a definite view to the future. In the ascending scale of organic nature, Intelligence first appears as the power of working towards a purpose; while Habit can only repeat former actions, either exactly or with purposeless variations.

Habit and Intelligence are Factors in all Life.—This contrast between the functions of Habit and of Intelligence would be more evident if we had to deal with them in the sphere of consciousness alone. But Habit is in general regarded as belonging chiefly to the motor system; it is scarcely yet recognised that, on the one hand, the perpetuation of organic characters by descent, and their changes by variation, occur under the laws of Habit; and, on the other hand, that the Association of Ideas, a law

which is fundamental in psychology, is nothing more than Habit acting within consciousness. Still less is it recognised that Intelligence is not confined to the sphere of consciousness;—that the Intelligence which organizes the body is the same which becomes conscious in the mind; and that animal instinct constitutes the transition between the two. To prove these is part of the purpose of this work.

Unconscious Intelligence is not more unintelligible than Unconscious Force.—Many readers are inclined to object to the conception of unconscious organizing Intelligence, as being unintelligible. My reply to this is, that unconscious Intelligence is neither more nor less unintelligible than unconscious Force. It is in reality absolutely unintelligible, or perhaps we should rather say inexplicable, that any force—the force of gravitation or any other—should be exerted by an unconscious agent; and only the blinding effect of familiarity can prevent the mystery from being recognised as such. It may be said, and it appears to be the general belief, that the organizing Intelligence is directly Divine; and it may be said, and has been maintained, that the gravitative and all other physical forces are direct exertions of Divine power. Those who accept one of these conclusions ought to see no difficulty in accepting the other; and the objections to both appear equally strong.

Darwin's Theory.—The question of the nature of the Organizing Power is greatly complicated by the apparently purposeless variations to which all living forms and functions appear to be subject. Darwin, as we have seen, endeavours to prove that the existence of an Organizing Intelligence is a needless hypothesis; and that all those wonderful facts of organization which appear so far beyond the power of any unintelligent agent to produce, are really due, partly to the power of self-adaptation to new circumstances, which depends on the law of Habit, and probably exists in some degree among all organisms; but chiefly to natural selection among spontaneous variations, ensuring

the survival of the fittest, and accumulating by hereditary transmission.

There can be no doubt that natural selection is a real agency of great importance; and, inasmuch as it is certain that on the whole the fittest will be selected and will survive, it is in one sense true that every species which exists owes its existence to natural selection. But we cannot accept this as a full account of the matter.

Insufficiency of Darwin's Theory.—In the first place, we have seen that, by Darwin's own admission, though natural selection will be absolutely certain to preserve favoured *races* when sufficiently numerous, it will give only a slight extra chance to favoured *individuals;* and that the probability is greatly against the preservation of the most favourable variation if it occurs only once.

Inadequate length of Geological Time.—In the next place, what we have called the Darwinian process—namely, the process of change and evolution by means of natural selection among slight spontaneous variations—is admittedly a very slow one; and we have argued that even if the evolution of the highest warm-blooded air-breathing vertebrate forms out of the earliest minute masses of vitalized jelly is conceivable, and theoretically possible, as the result of mere natural selection among spontaneous variations, yet the longest geological periods that modern physical science can allow, are much too short for such a process.

Sudden and definite Variation. Facts of Classification inconsistent with Darwin's Theory.—Further: while we fully agree with Darwin in recognising general diffused slight variability as a fact of organic nature, yet there are other laws of variation which are not yet understood. Variations are often so sudden and so definite as to constitute what are morphologically new species at once; and many organic characters, constituting the differentia of entire groups, must, from the nature of the

case, have arisen suddenly; such as the place of insertion of the stamens in flowers, and the character of the scales in fishes. Such characters as these last mentioned have nothing to do with the welfare or the general life of the species; yet they are tolerably constant throughout wide groups, and are consequently of great importance in classification. This seems to prove that natural selection cannot be the sole nor the chief agency in fixing the characters of groups; for if it were so, those characters which are of the least importance to the life and welfare of the species would be left unfixed and variable; whereas the contrary is the case; those characters which have the least connexion with the life or special habits are generally the least variable within the group, and are consequently of the most importance in classification.

Parallel Variations.—We have also seen that in many cases the same characters have appeared at different times and in different groups. Thus among fishes, similar scales are found in different groups, where the rest of the affinities show that they cannot be due to a common descent; and the same is true of the forward position of the ventral fins, which constitutes so remarkable a character in some families of fishes. Such facts as these seem to prove that slow spontaneous variability cannot be the sole explanation of the origin of characters, nor can natural selection be the chief cause of their fixation.

Delbœuf's Law.—We have also seen that, in virtue of Delbœuf's law, if any particular variation occurs in a proportion which is not infinitesimally small of all the births among a species, and if neither the variation nor the original form has any advantage over the other which will cause it to prevail by natural selection, the numbers of the two will gradually approximate indefinitely near to equality.

The Formative Impulse.—The foregoing remarks do not throw light on the origin of characters. But we have seen that the

facts of metamorphosis and metagenesis are in many eases inexplicable by any other supposition than that of a formative impulse impressed on living matter at the beginning. The theory of Evolution makes it probable that in most cases of metamorphosis, the larval or immature form preserves the likeness of an ancestral form, so that the metamorphosis of the individual is a picture of the evolution of the race. But in many of the metamorphoses of the Crustacea, and probably also in those of the Echinodermata, and in the metagenesis of the Hydrozoa, there is no change in the dwelling-place or in the mode of life to which the ehange in organization can be referred; so that natural selection among small spontaneous variations appears an inadequate cause for the transition, and it appears impossible to assign any cause except an internal formative impulse.

It may be said that this explains nothing, and is only a name for our ignorance. There is a sense in which this is true, for every inquiry into nature leads up to something which cannot be explained; but it is not necessarily more true of the doctrine of a vital formative impulse than of the doctrine of gravitation; which, though proved as a faet, may perhaps ever remain inexplieable.

Structure in anticipation of Function. Development of Mind and Language.—We have moreover seen reason to believe that the formative impulse, or organizing power, acts not blindly, but with foresight and purpose. Besides the general reason for so believing, namely that organic adaptation transeends the power of any unintelligent agent, there is also this special reason, that the facts of comparative morphology appear to show, in different parts of the animal kingdom, what we have ealled structure in anticipation of function:—structures which, when they first appear, are imperfect and useless, and therefore cannot owe their origin or their preservation to either self-adaptation or natural selection; for self-adaptation can suit the organism only to the actual circumstanees of its life, and natural selection can preserve only what is immediately useful. Sueh structures have

been formed, not for the wants of the organisms possessing them, but in anticipation of their usefulness when perfected after millions of generations. It seems probable that such instances are to be found almost everywhere in the organic creation;—the most remarkable which we have been able to identify are at the opposite extremes of the Vertebrata. The first beginning of vertebrate organization is to be seen in the larvæ of some Ascidians, to which minute and lowly organisms it seems impossible that such structure can be of any use; yet a similar structure is formed in all vertebrate embryos, and develops into the spine and the spinal cord, which are the characteristic and fundamental parts of the osseous and the nervous systems of the highest animals. And, at the other extreme of the vertebrate scale, the development of Man's brain, which is the organ of his mind, and the development of language, which is the first and most characteristic product of his mind, unite in showing that the nervous and mental organization of the entire human species is far in advance of the needs of prehistoric Man, and have from the first been laid down on a scale adequate to the wants of the highest culture and civilization. This is probably the most clearly established of all cases of structure in anticipation of function; and it is evident that one such case, if proved, suffices to prove that the theory of natural selection, though true up to a certain point, is not all-explaining.

Instinct.—An examination of the facts of Instinct has led us to a similar conclusion;—namely, that there are instinctive powers which cannot be due to natural selection or any other unintelligent agency, because the past life of the species cannot have given occasion for the evolution of such powers through their exercise.

Mental Intelligence. Belief. Spiritual Intelligence.—Lastly, when Intelligence becomes combined with Consciousness and constitutes Mind, we find that its action cannot be interpreted as due to the resultant of any unintelligent powers. Especially

is this shown in the power of Belief, which, as we have seen reason to conclude, is different in kind from any power that could possibly be developed out of the merely habitual and unintelligent nature. We have also seen reason to conclude that our conceptions of Time, Space, and Causation, cannot be accounted for by any merely habitual or unintelligent action of the mind; and the same is still more decidedly and obviously true of Man's moral nature, which latter can only be interpreted as the result and expression of a spiritual power, transcending not only all Habit but all merely vital Intelligence.

Habit and Intelligence are always combined.—Though we are compelled to regard Habit and Intelligence as distinct in thought, yet they are always combined in fact; they both belong to all life; and Intelligence presupposes Habit. Habit is the power which retains and registers experiences; Memory is Habit acting within the sphere of consciousness. Thus Habit and Memory furnish the materials whereon organizing, instinctive, and mental Intelligence work to the attainment of higher results.

Reality of Mental Agency.—In the chapter on Automatism we have maintained that mental agency is real, and that Consciousness, which is unquestionably an effect of physical action, is capable, under the name of Will, of becoming in its turn a cause of physical action.

The apparent simplicity of Automatism and Darwinism is contrary to the analogy of Nature.—The theories which would resolve Mind into automatic nervous action, Intelligence into a resultant from the habitual powers, the origin of organic forms into an effect of self-adaptation and natural selection, and Life itself into a chemical process, have a charm for many, which seems to consist in their apparent simplicity. But simplicity is no criterion of truth, and the analogies of nature are rather against expecting this kind of simplicity in the organic creation.

In nature there is a succession of ascending stages, and the laws and properties of each are not deducible from those of the preceding. The properties of matter and force presuppose those of time and space, yet they are not deducible therefrom; and the chemical properties of matter, which are different for every element, are not deducible from inertia and gravitation, which are the only dynamical properties common to all matter. It is thus consistent with analogy if we are right in maintaining that Life with its habitual powers is not a resultant from any physico-chemical forces, nor Intelligence from Habit, nor moral Intelligence, with the sense of Holiness, from merely mental Intelligence.

In what sense Man is a distinct Creation.—These considerations furnish the reply to an argument against the doctrine of Evolution, which appears to have weight with many;—I mean the notion that where change is gradual it cannot be fundamental; and consequently if Man has been developed out of the Ape, he is still an ape. Without entering on any logical or metaphysical discussion, we reply that such is not the fact; a gradual change by development may be a fundamental change. The difficulty, whatever it amounts to, of conceiving how such a being as Man can be descended from an Ape, the Ape from a Fish, and the Fish from a Protozoon, is paralleled in the life of every human being. The child, before it learns to speak, appears to have no higher mental nature than that of an intelligent dog; for some time after birth it appears to have no mental nature at all; and immediately after conception it has no higher organic nature than that of a Protozoon. The development of the individual is in the highest degree mysterious; but the mystery is only repeated, and the difficulty is not increased, if it is true, as the doctrine of Evolution teaches, that the development of the individual, from the structureless germ up to the mature Man, has had its parallel in the development of the race. The relation of Man's spiritual to his animal nature is no doubt one of the greatest of all mysteries; but the

relation of life to matter, though a lower kind of mystery, is equally mysterious. No physical science can elucidate the relation of the spirit to the brain; but the fact that Man's brain has no superiority to that of the highest Apes from which his spiritual superiority could possibly be guessed, so far from giving support to a materialistic view of our spiritual nature, rather tends to cut away the ground from under any materialistic argument. The question, what point in the development, either of the individual or of the race, is that where the spiritual nature has come in, cannot be answered, but is not an important one to answer. It is however in accordance with all the analogies of creation, if the same Creative Power which at the beginning created matter and afterwards gave it life, finally, when the action of that life had developed the bodily frame and the instinctive mental powers of Man, completed the work by breathing into Man a breath of higher and spiritual life.

THE END.

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183 Coccus apterus
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